Carlijn Valk

PhD Thesis

CONTEXT MATTERS

PERSONALIZING BEHAVIOR CHANGE STRATEGIES TOWARD MOTIVATING OLDER ADULTS TO BE MORE PHYSICALLY ACTIVE

Doctoral Thesis

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Proefschrift

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PERSONALIZING BEHAVIOR CHANGE STRATEGIES TOWARD MOTIVATING OLDER ADULTS TO BE MORE PHYSICALLY ACTIVE

Doctoral Thesis

to obtain the degree of doctor from
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on the authority of the Rector Magnificus
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by

Carlijn Anne Lieke Valk

born in Leiden, the Netherlands

This thesis has been approved by the supervisors and the composition of the Doctoral Committee is as follows:

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Advisor:	**Dr. Emilia Barakova**

The research described in this thesis has been carried out in accordance with the TU/e Code of Conduct for Scientific Practice.

To the men and women at the

Ontmoet & Groet Huys

without whom this work would not have been possible

and especially to

Dr. Anneke Schreuder

without whom we would have never known I had it in me

Summary

As we age, we tend to become less active which exasperates the severity of a variety of chronic conditions increasing our need for care. Physical activity has many proven benefits for older adults including supporting independence, decreasing the symptoms of frailty and supporting an overall feeling of wellbeing. There is a clear need to create behavior change (BC) solutions to motivate older adults to engage in a healthy amount of physical activity not just to alleviate the pressure on Europe's healthcare system but more importantly to support their happiness and wellbeing.

Though behavior change is a well-studied field of research, limited work has focused on designing personalized behavior change technologies for older adults. It is therefore unclear how to profile older adults in order to inform the use of behavior change strategies to motivate increased physical activity. This lack of focus is due, in part, to barriers that exist preventing an important subset of older adults to engage in research towards the development of new technologies. Consequently, there are two important research questions to address here:

RQ1: How can we effectively personalize behavior change solutions for older adults to motivate increased physical activity towards a healthier lifestyle?

RQ2: How can we overcome the barriers to engage older adults in research related to technology development?

Method. We carried out a general research process consisting of exploring, designing and evaluating to address our research questions. During the exploration phase we conducted two studies. The first aimed to better understand which behavior change strategies might be promising for older adults. The second study was a field study to gain a better understanding of the barriers that older adults face to research participation using both cultural and technological probes. In the design phase we built a system to engage older adults in research and created two mobile applications aimed at motivating increased physical activity. In our final study we evaluated the effect of the two mobile applications had on participant's physical activity and whether the system we created supported research engagement in an in-context research towards behavior change technology development.

Results. In the first study of our exploration phase, we analyzed the outcomes of twelve iterative user focused design processes by student teams and found that 'self-awareness' and 'social fitness' were the two most common strategies used to motivate increased physical activity among older adults (Valk et al. 2017). In the second study, we were able to identify barriers and facilitators to technology acceptance by taking a critical theoretical reflection of data collected from 44 community-dwelling older adults using a commercially available wearable activity tracker over a period of three months (Valk et al. 2018). Based on these results, we proposed a set of codesign strategies to address technology acceptance among older adults to be used in the design of future wearable tracking technologies (Valk et al. 2018). These strategies were used in our design phase to create a specific product-service-system to support older adults to engage in an in-context behavior change research (Valk et al. 2019). Also, in the design phase, we created two mobile applications, through a codesign process with older adults, which implemented the behavior change strategies identified in the first study. During our evaluation phase we used the product-service-system we created to enable the nine-week randomized controlled trial (N=53) in-context evaluation of the two mobile applications (Valk et al. 2019). Based on the statistical analysis of the measured step data and the collected questionnaire data, we suggested how to create effective motivational profiles to personalize these behavior change strategies toward increased physical activity for older users.

Contribution. To address our first research question, we propose a way of creating motivational profiles linked to behavior change strategies. To address our second research question, we provide design criteria for the setup and execution of design research to overcome the barriers to research participation. Here we establish the importance of inclusivity in both the final design solution and in the design process, so that even initially nontechnology savvy older people can benefit from technologies potential to motivate healthy behavior change.

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Part One

BACKGROUND

This thesis will be divided into five parts following the general phases of our design research process: Background, Explore, Design, Evaluation and Reflection. In this first part we aim to provide relevant background information to support our subsequent research activities in later phases of the design research process described in later parts of this thesis. To this end, we will fist provide an introduction of the topics to be discussed in this thesis in chapter one. In chapter two, we will discuss relevant related work in order to better position our research questions among previous work. Building off of the work presented in chapter two and the areas of interest presented in chapter one, we will present the objectives of this work in chapter three.

CHAPTER ONE

Introduction Motivation & Research Questions

As advances in medical science continue to raise the quality of healthcare around the world, we face new opportunities and challenges to also facilitate the maintenance of an individual's quality of living throughout their lives. Across Europe, and for many reasons, we happily observe a higher life expectancy. With more people living in advanced age, it is increasingly important to acknowledge necessary changes to the current health care system to accommodate this change in demographic. However, the responsibility of care and quality of life does not solely rest on the hardworking health care professionals; making healthy lifestyle choices greatly supports both health and overall wellbeing, especially in people of advanced age or older adults.

However, most of us can relate to the difficulties in maintaining these healthy lifestyle choices over a period of time until they become adopted as a new healthy habit. Older adults, especially, face challenges to maintain a healthy amount of physical activity. As designers, we should work towards creating behavior change solutions which support older adults to adopt a healthier lifestyle through a healthy amount of exercise. In this way we empower our users to have more agency over their health, and ultimately, their quality of life.

Europe's Aging Society: Trends in Care

The European Council recognizes the need to address Europe's growing population of older adults, caused by the rise in life expectancy and decreased fertility rates (Part et al. 2015). By 2060, the number of working-age adults for every person 65 years of age and older will have decreased from the present four to only two, overtaxing the current healthcare system (Part et al. 2015). The European Commission published that the overall fertility rate in Europe is projected to increase from 1.59 in 2013 to 1.68 by 2030 and 1.76 by 2060, but will remain below 2.1, the natural population replacement rate (Rechel et al. 2013). In addition, life expectancy in the EU is projected to increase 7.1 years for men and 6 years for women, between 2015 and 2060 (European Commission 2015). These circumstances will lead to significant growth in Europe's older adult population.

The rapid growth of Europe's older adults population, will put increased pressure on working-tax payers who largely finance Europe's health care systems (Part et al. 2015). The European Commission (Part et al. 2015) has identified that demand for care, and thus care-related expenses, increases with age as, with age we, are more likely to suffer multiple comorbid conditions and chronic diseases, such as frailty which inhibits independence and increases our need for care. These findings are echoed by Sneha (Sneha and Varshney 2008) and LeRouge (LeRouge et al. 2011). The European Union will see a substantial increase in public spending on long-term care for older adults; between 2007 and 2060 public spending will almost double from 1.2% to 2.3% of GDP in the EU (Rechel et al. 2013). This increased demand for medical care with age can in part be explained by the relative lack of successful medical innovations to treat chronic diseases, despite advances made to decrease the number of fatal diseases (Part et al. 2015). Due to success in medical advances people live longer and inevitably age-related chronic diseases increase the demand for care. As European member states cut public spending on professional care homes for their older adults, strain and stress on family and other informal care providers who step in to replace formal care increases (Christensen et al. 2009; Part et al. 2015). Addressing the high costs associated with health care in older age can potentially solve Europe's approaching health care cost dilemma (Rechel et al. 2013). From this it is clear that, from a financial perspective, Europe will need to address the challenges that come with health in older age.

Benefits of LifeStyle Related Preventative Health

It is clear that for many reasons, we enjoy a higher life expectancy in Europe and thus it is important to address the needs, opportunities and challenges which this development yields in our society. Addressing these is important to support quality of life in older age and to lessen the pressure on Europe's health care system in order to maintain the quality of care. One important way to facilitate both this increased quality of life and the support the EU health care system is to facilitate proactive preventative care through supporting healthy lifestyles, by facilitating increased physical activity.

Physical activity here will refer to bodily movement as a result of an exertion by the musculoskeletal system (Schutzer and Graves 2004; WHO 2018). While exercise is treated here as a more specific term to indicate physical activity towards the pursuit of increased levels of fitness, usually within some kind of structured program (Schutzer and Graves 2004). While both physical activity and exercise can lead to health benefits, there is much evidence to suggest that moderate intensity physical activity such as walking, or cycling yields many health benefits specifically for older adults (Jonkman et al. 2018). Physical activity has been shown to maintain muscle strength and bone density and improve the physical functioning required for activities of daily living (Bauman et al. 2016). Physical activity has been found to have a positive effect on social involvement, self-esteem, stress reduction, cognitive function, maintenance of bone density and muscle strength, and chronic disease risk reduction (Bauman et al. 2016) Increased physical activity in seniors has been shown to not only improve psychological wellbeing and overall quality of life but also to prolong independence of care (Warburton, Nicol, and Bredin 2006). In contrast, sedentary behavior has been linked to coronary disease, type 2 diabetes, certain types of cancer and other causes of premature mortality (Lee et al. 2012).

Activating Europe's older adult population has clear health benefits and also contributes to a better quality of life by enabling older adults to remain independent longer, reducing pressure on informal care providers. European officials recognize stimulating physical activity among community dwelling older adults as an important part of healthy ageing by investing in research and innovation projects such as the REACH Horizon 2020 project, which aims to stimulate responsive engagement of the elderly promoting activity and customized healthcare in order to support the

care and quality of life of older adults in Europe (for more details see reach2020.eu). Adopting a more active lifestyle is one of the surest, "means of postponing the onset of functional decline, promoting independence, and maintaining a high quality of life in old age" (Chodzko-Zajko, Schwingel, and Park 2009), while sedentary behavior will have negative health consequences (Dunstan, Thorp, and Healy 2011; Greenwood-Hickman, Renz, and Rosenberg 2016; Warburton et al. 2006). Despite these clear health benefits, the senior population currently displays the most sedentary behavior, of any age group (Matthews et al. 2012; De Rezende et al. 2014), often spending about 80% of their waking hours in an idle manner (Davis et al. 2011). The challenge is how to motivate older adults to adopt a more active lifestyle, increase this population's independence, and ultimately improve their quality of life.

To summarize, although there is no way to prevent the natural functional decline that comes with aging, an increase in physical activity can support longer independence, reduce the need for costly care and ultimately improve the quality of life at advanced age. The question remains: how can we motivate the older adult population to adopt a more active lifestyle?

Design for Behavior Change

Behavior change (BC) is a dynamic process describing the adoption of new habits and routines sometimes in the place of old ones. Behavior change is difficult to achieve and especially, to maintain. In the past researchers have attempted to define strategies to stimulate people to achieve and maintain their target behavior.

Roughly existing literature on behavior change can be divided into fundamental theories or actionable theories. In which distinguishing factor is that the observational theories describe the process of behavior change as it can be observed and investigated while the actionable theories provide frameworks and structures aimed at providing specific knowledge towards enabling behavior change. Much of the existing observational behavior change literature is built off of fundamental theories

in which early pioneers of the field, as far back as the Greek philosophers, tried to describe the internal mechanisms at work in humans which result in our behaviors (Higgins 2006). On these fundamental theories work was built which largely divided experts into two camps; the rational choice theorists and the learning theorists. The rational choice theories see behavior as a direct result of intention through consideration while the learning theories see behavior as a function of an individual's perception of the potential outcome of an action and their own ability to accomplish it, while acknowledging the influence context may have. Though this is not a perfect division and these camps are not necessarily mutually exclusive as they have some overlapping understanding of factors which influence behavior, this division helps us highlight the development of behavior change theories and models over time and thought.

Some fundamental observational behavior change theories focuses on describing the psychological elements that lead to behavior change. Ryan and Deci's Self Determination theory describes three different motivators correlating to three innate human needs; competence (feeling over control over one's situation), relatedness (feeling of connectedness to others), and autonomy (feeling of free will) (Ryan and Deci 2000). Ryan and Deci (Ryan and Deci 2000) describe basic human needs which may act as motivators; these fundamental motivators are not easy to translate into practical strategies toward design for behavior change. In our continued search for relevant frameworks we found Prochaska and Velicer's Trans-Theoretical Model (TTM) (Prochaska and Velicer 1997) of behavior change both descriptive and actionable. The TTM describes behavior change as a process over time with various stages of openness to adapting to new behavior, from ambivalence to determination (Prochaska and Velicer 1997). The TTM allows designers to gain a better understanding of the dynamic state of mind their user is in when moving through the process of behavior change. This model, like most other observational behavior change theories, does not provide suggestions as to how to match user needs in each of these stages with the appropriate design strategies.

Fogg's Behavior Model (Fogg 2009) could be described as both an observational and an actionable theory as it describes what must occur to induce the user to perform a target action, and includes designer suggestions. Fogg's model proposes that the likelihood of adoption of the desired behavior is related to the user's motivation to complete the task, and their ability to do so (Fogg 2009). Fogg (Fogg 2009) determined that the higher an individual's motivation, the more inclined they will be to take action, even if the task is difficult. Fogg (Fogg 2009)also asserted that if an

individual's motivation is low and the target behavior needs to require very little effort, individual's ability needs to be high, for the individual to perform the behavior (Fogg 2009). Although Fogg's valuable insights establish some notion of requirements for triggering behavior, this model does not provide strategies about how to create fitting triggers applicable to design work for senior users.

A clear example of an actionable behavior change theory, the Behavior Change Wheel, a framework for characterizing and designing behavior change interventions by Michie (Michie, Stralen, and West 2011), suggests that different behavior change design policies can be implemented through any of Michie's identified interventions. The outermost ring of the Behavior Change Wheel is called policies and refers to drivers from responsible parties, which enable or facilitate interventions, targeting behavior change (Michie et al. 2011). Unfortunately, none of these actionable frameworks provide concrete strategies for applying interventions in projects aimed at stimulating older adults to be more physically active.

Other literature is highly specific in providing concrete suggestions about how to attain lasting behavior change. Culos-Reed (Culos-Reed et al. 2000) writes on the Predictors of Adherence to Behaviour Change Interventions in the Elderly and describes determinants of an individual's likelihood of following through with a healthier lifestyle. Culos-Reed (Culos-Reed et al. 2000) states that one's perception of one's own ability to successfully achieve a goal and one's past exercise habits are the most important indicators of whether an individual will adopt the target behavior and that social support plays a major role in adopting new habits of increased physical activity and diet.

Consolvo (Consolvo, McDonalsd, and Landay 2009) describes design strategies for lifestyle behavior change technologies. Characteristics of effective behavior change design should, according to Consolvo (Consolvo et al. 2009), be abstract enough to encourage the user to reflect, be unobtrusive to user's other activities, not be objectionable to the user if shared in a public space, be attractive and aesthetic, be positive, allow the user to have ownership of the system, allow user to track their change over time, and be comprehensive enough to address a variety of user needs related to their changing behavior (Consolvo et al. 2009). Consolvo (Consolvo et al. 2009) provides significant insights into the needs of users in terms of behavior change, however the strategies proposed might be better suited to function as overall design requirements, rather than a systemic overview of design approach strategy, as these high-level concepts can still be challenging to implement in a design process.

Oinas-Kukkonen and Hajumaa (Oinas-kukkonen and Harjumaa 2009) provide clear persuasive strategies in their article, Persuasive Systems Design (PSD). They outline four main system qualities (Primary Task Support, Dialogue Support, System Credibility Support, and Social Support). Each of these principles is further divided into descriptive design principles, referred to as persuasive principles. These persuasive principles can be used to classify the motivational drivers behind products, which aim to change user behavior toward a healthier lifestyle. Yet it is still unclear how these persuasive principles can be applied to create motivational drivers to promote physical activities among senior citizens.

Previous work to facilitate behavior change targeted towards an already motivated audience, such as a running application for already dedicated runners, often depend on the intrinsic motivation of the user and are inappropriate for those yet unmotivated to adopt a healthier lifestyle (Campbell et al. 1994). The growing population of sedentary older adults is not necessarily motivated to engage in enough regular physical activity, and thus likely require a different approach to motivate them to move more. This calls for research actions to explore ways in which persuasive strategies can be applied to adapt existing products, intended for physically active younger adults, to stimulate older users to adopt a more active lifestyle.

One thing which is clear however; personalization tends to increase the adoption of behavior change solutions and the effectiveness of these interventions. Personalization is very important if not essential to behavior change (Kaptein, Markopoulos, et al. 2015; Kaptein, Parvinen, and Pöyry 2015), as personalized messages have already been shown to improve the target audience's adherence to a desired behavior (Purpura et al. 2011). This might be especially true in such a diverse population such as older adults (LeRouge et al. 2011). To explore the importance of motivation profiling, Friederichs et al (2015) examined physical activity level, demographics, motivation to be active and subjective experience while being active of 2473 adults (31.4% male; age 44.6 +/- 12.9) who did not comply with physical activity guidelines (Friederichs et al. 2015). Based on motivational regulation scores three clusters emerged; low motivation, controlled motivation and autonomous motivation cluster, between which significant differences were found in terms of physical activity, motivation to be active and subject experience while being active (Friederichs et al. 2015). From this study the authors conclude that individuals within each cluster might benefit from different behavior change strategies to motivate increased physical activity (Friederichs et al. 2015). Authors call for psychographic segmentation, which in essence seeks to profile individuals based on values, interests and lifestyle elements in order to better

address needs and motives (Hardcastle and Hagger 2016). From the learning theories mentioned above we realize that the there is no clear consensus on which exact determinants or personal factors which should be used to profile individuals and inform appropriate personalization. Though the investigation into which determinates should be used to profile individuals in order to effetely personalize behavior change strategies, it is clear that personalization is essential to the effectivity of these activity stimulating behavior change solutions.

New activity tracking technologies have been used to stimulate increased physical activity and accompanying mobile applications can be personalized to increase the efficacy of these behavior change solutions. Bianco et. al. 2015 (Lo Bianco et al. 2015), demonstrates technologies potential by showing that Human-Computer Interaction (HCI) offers opportunities to create more personalized interventions for a more individualized approach to fall prevention. Technologies potential to support personalized behavior change solutions should be further investigated.

Behavior Change Technologies

New wearable sensing and monitoring technologies hold potential to support an increase in physical activity (Jonkman et al. 2018; Kononova et al. 2019). Due to the wide scale assumed success and importance of this potential to get people to avoid a sedentary lifestyle, wearable technology market leaders like Fitbit have introduced "inactivity alerts" in all but their simplest devices. Further early research has shown that many intelligent technologies can offer a lot of opportunities to support older adults to cope with the changes of aging and remain healthy and active (Blaschke, Freddolino, & Mullen, 2009). The introduction of these sensors and monitoring technologies are hoped to have a positive effect on the amount of physical activity older adults do (Randriambelonoro, Chen, Yuruten, & Pu, 2017). Unfortunately, for a certain subset of the older adult population, the acceptance of these wearable devices remains a challenge (Charness and Boot 2009; Peek 2017). The lack of technology acceptance can form a barrier to the adoption of these technologies. Older adults are a highly diverse population in many aspects including health, mobility, to what extent they engage in physical activity, and level of technological acceptance and adoption. Here we will focuses on the subset of people from this diverse group, who could benefit from sensing and monitoring technologies, which can enable them to track their activity and other health indicators, yet who face barriers preventing them from accepting and adopting these technologies.

Available off-the-shelf wearable sensors do not address the specific needs and barriers of this older target user group. There is a tendency to assume that it is enough for behavior change solutions to adhere to accepted accessibility guidelines yet sources indicate that designing technological interventions in such a way to make them acceptable to older adults unused to digital technologies is often not enough to result in the adoption, or regular use, of that intervention (Renaud and Biljon 2008). This is because even if an interface is usable for older audiences (consider color contrast, font size, etc.) it does not mean this intervention is relevant to older adults' values and daily lives.

Older adults who face barriers to technology acceptance may also face barriers to research engagement (Chen and Chan 2011; Mitzner et al. 2010; Valenzuela et al. 2018). It can be difficult to engage older individuals who have limited experience with digital devices in research studies towards the development of new technologies (Eisma et al. 2004; Kopeć, Nielek, and Wierzbicki 2018). Researchers face challenges to overcome these barriers to research participation and engage older adults with limited technology acceptance in research towards the development of new technologies (Binda, Wang, and Carroll 2018; Eisma et al. 2004; Harrington et al. 2018; Holroyd-Leduc et al. 2016).

Motivation and Research Question

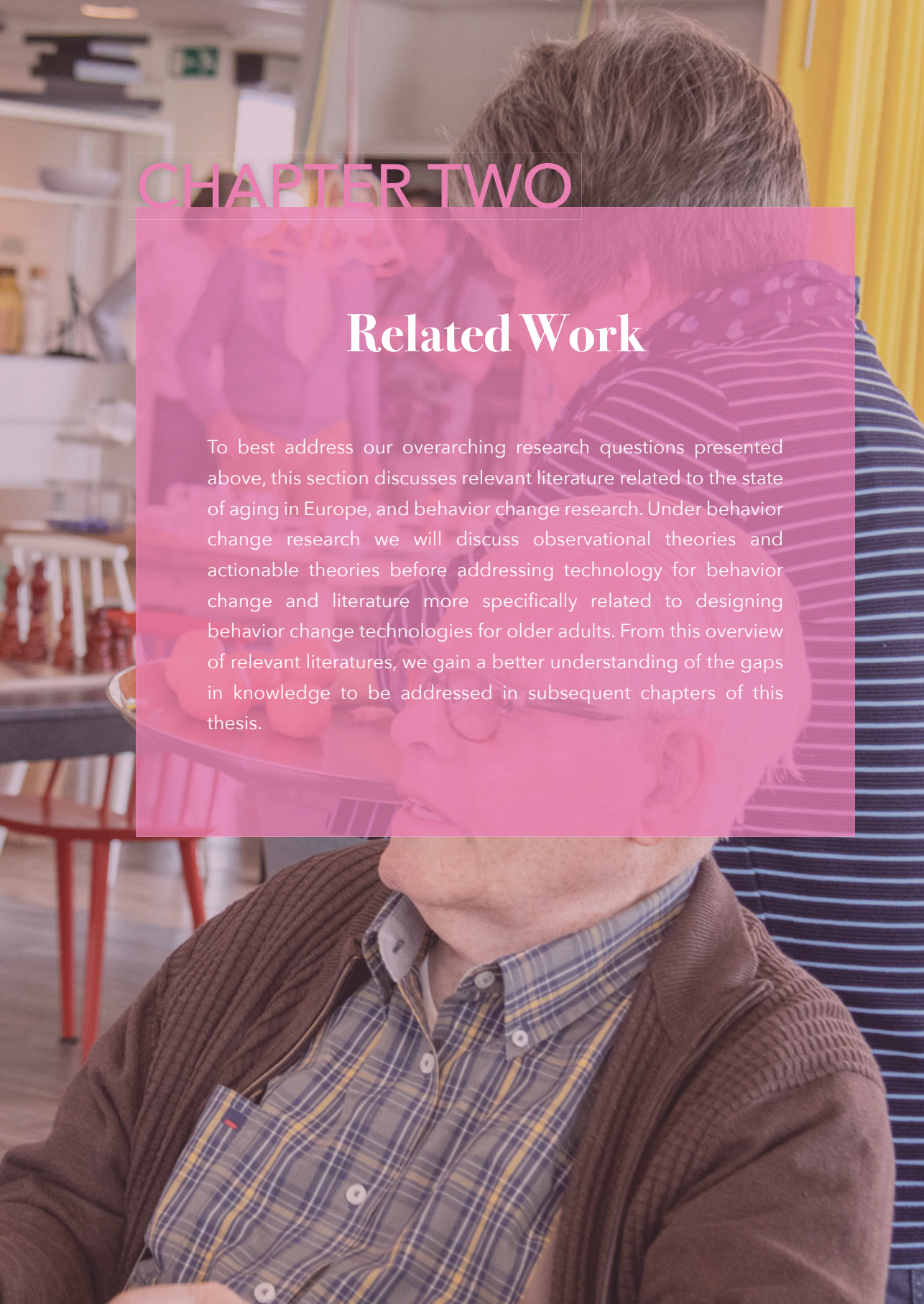
Sedentary lifestyles threaten the independence and wellbeing of the rapidly growing older adult population (De Rezende et al. 2014), even though the benefits of physical activity seem to be common knowledge. This lack of physical activity contributes to symptoms of frailty (Chodzko-Zajko et al. 2009) as well as other chronic conditions which adds to the strain on the European health care system. Maintaining a healthy amount of physical activity can increase older adult's independence (Bauman et al. 2016) and improve their overall experience of wellbeing. There is a clear need to use behavior change to motivate increased physical activity in older adults.

Technology has shown the potential to motivate increased physical activity due to its propensity to offer personalized interfaces, but current behavior changes interventions alienate older users with limited experience with digital devices. More research needs to be done to better understand how to appropriately address older adults with such technology-based behavior change interventions. In order to enable this important research we need to enable older adult's participation in research aimed toward technology development. Thus, in this thesis we will aim to address the following main research questions:

RQ1: How can we effectively personalize behavior change solutions for older adults to motivate increased physical activity towards a healthier lifestyle?

RQ2: How can we overcome the barriers to engage older adults in research related to technology development?

To best address these important research questions chapter two will discuss relevant literature on the subjects, and chapter three will describe our approach to answer these questions. The remaining chapters have been divided into three parts which represent our three-part design approach. In part one, chapters four through six, we elaborate how we explored this subject matter. In part two we describe the design phase. In part three, chapters eight through eleven, we describe our evaluation studies and discuss our overall results before concluding the main learnings form this process.



CHAPTER TWO

Related Work

To best address our overarching research questions presented above, this section discusses relevant literature related to the state of aging in Europe, and behavior change research. Under behavior change research we will discuss observational theories and actionable theories before addressing technology for behavior change and literature more specifically related to designing behavior change technologies for older adults. From this overview of relevant literatures, we gain a better understanding of the gaps in knowledge to be addressed in subsequent chapters of this thesis.

Healthy Aging and Diversity: The State of Aging in Europe

Between 2015 and 2030 the World Health Organization (WHO) will refocus their work on aging to enable *healthy aging*, updating their previous *active aging* policy framework developed in 2002 (WHO 2020). Though similar in that both terms emphasize a multifaceted approach to support quality of life in older age, active aging focused on optimizing opportunities for health, participation and security while healthy aging concentrates on facilitating functional ability to enable a higher quality of life (Abyad 2018). WHO defines healthy aging as "as the process of developing and maintaining the functional ability that enables wellbeing in older age" (Abyad 2018; WHO 2020).

Growing Numbers and the Cost of Care

The demographic proportions in Europe are changing. Over the years, the European people have enjoyed an increased and improved level of welfare and health care services resulting in a higher life expectancy (Kroneman et al. 2016). Between 2016 and 2070 the life expectancy in Europe is projected to increase 7.8 years for males, from 78.3 to 86.1 years and 6.6 years for females, from 83.7 to 90.3 years (European Commission, 2017). At the same time, the birth rate or total fertility rate (TFR) in Europe, although there are differences among member states, is not expected to rise in a way to balance the increase of the older adult population (European Commission 2017). In general, the EU's population is projected to grow from 511 million in 2016 to 528 million in 2040, to remain stable until 2050 and to decline in 2070 (European Commission, 2017). Migration flow is also predicted to decrease over the very long (European Commission, 2017). These patterns of fertility, life expectancy and migration, point to a disproportionate growth among the population of people aged 65 and over as compared to other age groups.

The ratio of people aged 65 years or above to those between the ages of 15 and 64 is projected to increase significantly. In 2010 this ratio was about 25%, six years later it was already 29.6% and it is further predicted to increase to 51.2% in 2070 (European Commission, 2017). Though many sources cite slightly different numbers in their predictions, there is a general consensus that there will be a much higher number of older adults for every working aged person in Europe in the future as compared

to the present (European Commission, 2017; Nagarajan, Teixeira, and Silva 2016; Weil 2006). This demographic change presents certain challenges to the healthcare system.

Many have referred to this change in the demographic distribution as the 'ageing crisis' because this change has implications for the health care system in Europe. This demographic shift puts pressure on the working aged taxpayers who largely fund the healthcare system in Europe, as it effectively doubles the dependency ratio (European Commission, 2017). Statistically, care costs rise with age as people of a more advanced age are more likely to have multi-morbidity conditions which require more medical care (Part et al. 2015). In addition, the number of people living with a chronic condition is said to rise from 32% in 2011 to 40% in 2030, as medical advances allow us to treat an increasing number of formerly terminal conditions (Kroneman et al. 2016), yet have not eradicated the conditions completely. The cost of care is thus expected to rise dramatically over the coming years, and it is not clear how Europe will be able to finance this important sector.

It is clear that to address the needs of the impending demographic shift, Europe will need to anticipate these needs and make necessary changes (Part et al. 2015). The challenge Europe faces is how to provide the quality healthcare to an increased number of older adults with diminished resources.

Benefits of Physical Activity

One way to address the growing cost of care in Europe is to improve the overall health of EU citizens. Many conditions which pose a burden to the healthcare system in Europe are lifestyle related (Dietz 1996; Farhud 2015; Patterson et al. 2018). By motivating people to maintain a healthy lifestyle we can seriously reduce the burden on the overall health care system. To this end, the active aging movement aims to support the health, wellbeing and independence of older adults (Foster and Walker 2014). Active aging should be seen as a comprehensive approach to aging and refers to a broad array of initiatives which support the independence and wellbeing of older adults through creating opportunities for older adults to contribute to society, either by remaining in the workforce longer or by volunteering their time, passing on their knowledge and skills and living with dignity and independently as longs as possible. As the population of older adults grows so does the importance of creating opportunities to support active ageing.

One crucial aspect in supporting the wellbeing and independence of older adults toward active aging is avoiding patterns of sedentary behavior by motivating and supporting the regular participation in physical activities. Sedentary behavior refers to any activities, besides sleeping, which are done in a sitting or reclining posture so that a low basal metabolic rate is maintained (De Rezende et al. 2014). Regular continued sedentary behavior for extended periods of time can have a negative impact on a person's health (Matthews et al. 2012). Reportedly sedentary behavior contributed to the burden of lifestyle related disease like cardiovascular disease and type 2 diabetes (Patterson et al. 2018). The World Health Organization claims that sedentary behavior is a leading mortality risk factor worldwide and that those who are insufficiently active have an increased risk of death of 20% to 30% as compared to those who engage in regular physical activity (WHO 2018). Among older adults this has been seen to contribute to symptoms of frailty, yet a sizable portion of older adults adopts a sedentary lifestyle (Chodzko-Zajko et al. 2009). Sedentary behavior therefore has very serious health risks to older adults.

In contrast, a healthy amount of physical activity has been shown to be very beneficial to one's overall health. There is an important difference between physical activity and exercise, which can also be beneficial (Schutzer and Graves 2004). Regular physical activity has been shown to improve balance and is praised as an effective preventative measure against dangerous falls (Lee et al. 2012; Lockett, Willis, and Edwards 2005; U.S. Department of Health and Human Services 1996) In certain cases, it has even been shown to revers symptoms of frailty, a serious state of increased vulnerability and decreased physiological function (Bauman et al. 2016) limiting mobility and independence. Though some form of age-related decline is considered inevitable, physical activity has been found to effectively postpone functional decline, and thus supporting independence and other contributors to high quality of life (Chodzko-Zajko et al. 2009). Physical activity has been shown to have a positive effect on chronic disease risk factors, improve musculoskeletal strength and has been linked to better mental health, social integration, reduced fall risk and overall quality of life (Chodzko-Zajko et al. 2009; U.S. Department of Health and Human Services 1996; Warburton et al. 2006). Physical activity supports the ability to perform activities of daily living and thus is particularly important to the independence of older adults (Warburton et al. 2006).

It is clear that physical activity yields many benefits for older adults which can consequently alleviate some of the pressure on the healthcare system in Europe. In order to support older adults to increase their physical activity, wellbeing and independence, we need to better understand how to motivate sedentary older adult to change their behavior towards more physical activity. In the next section we will cover important related literature on behavior change theories and strategies.

Behavior Change

To stimulate wellbeing among older adults, through increased physical activity, there is a need to understand the mechanisms of behavior change. The study of behavioral change has seen much progress over the last decades in which many experienced researchers have been working on this subject. To make a contribution in this well documented field, it is important to be aware of the work that has preceded ours so that we can learn from and be inspired by it. However, this is not the place to cover every known theory of behavior change from the past decades of work. We have therefore selected the most relevant work which has contributed to our work to and will provide a brief overview of those works here. In order to more effectively cover all of the valuable work that has been done in this field, we have selected only some of the most relevant works to give the overview and split these into two sections: the observational theories section and the actionable strategies. The observational theories largely aim to describe the mechanisms of behavior change, while the actionable strategies aim to provide guidance for those who aim to support or instigate behavior change.

Observational Theories

In this section we will discuss the observational theories which inspired the work presented in this thesis. We will first discuss theories which provide the earliest descriptions of the process of behavior change, termed fundamental theories here. Next we will discuss expectancy value theories or reasoned action theories, which build on the fundamental theories. Finally, we will discuss some of the learning theories, which largely enrich the reasoned action theories. Though there are a great many behavior change theories, most of them are largely based on these main theories discussed here, see details in Table 1.

TABLE 1: FUNDAMENTAL BEHAVIOR CHANGE THEORIES

FUNDAMENTAL THEORIES	Hedonic theory (Higgins 2006)
	Regulatory Focus theory (Brockner and Higgins 2001)
	Self-efficacy (Bandura 1977; Lee, Arthur, and Avis 2008)
	Transtheoretical Model Behavior Change (Prochaska and Velicer 1997)
REASONED ACTION THEORIES	Expectancy Value theory (Hsiao 2018; Opp 2014)
	Theory of reasoned action (Fishbein 2008)
	Theory of planned behavior (Fishbein 2008; Venkatesh, Thong, and Xu 2016)
	Protection Motivation (Prentice-Dunn and Rogers 1986)
	Health belief model (Skinner, Tiro, and Champion 2015)
LEARNING THEORIES	Social learning theory (Bandura 1971)
	Cognitive theory (Bandura 1999)

Fundamental Theories

The study of behavior change, the process of adapting patterns of behavior and adopting new target behaviors has interested scientists and philosophers alike throughout history. The ancient Greeks recognized the *Hedonic principle*, which states that humans are intrinsically motivated to move toward 'hedonic' or pleasurable experiences and away from painful ones. Much later, in the ninetieth century, Herbert Spencer formalized this fundamental principle into a psychological theory (Bozarth 1994). Others build on this early work to establish an array of different theories and perspectives on behavior change, examined through various different lenses. Since then, many authors have worked to form a better understanding of the process of behavior change and the factors that influence this.

In line with the Hedonic principle, the *Regulatory Focus Theory (RFT)* proposes two distinct hedonic self-regulatory systems which drive behavior depending on the needs an individual is trying to satisfy; the prevention or promotion regulatory focus (Brockner and Higgins 2001). The RFT suggests that promotion focused people are driven by needs based in growth and development while prevention focused people are driven by security needs (Brockner and Higgins 2001). Thus, people with a prevention focus, focus on the standards and expectations they "ought" to live up to, pertaining to their obligations and responsibilities. On the contrary, promotion focused people seek to attain their "ideal selves", focusing more on their hopes and aspirations. Brockner and Higgins suggest that people have an individual dispositional tendency toward one or the other focus, yet also acknowledge that socio-cultural

context can affect if a person is motivated more by prevention or promotion (Higgins 1997). While the Brockner and Higgins focus on the regulatory focus of the individual and how this motivates them to perform certain behaviors, they do acknowledge the influence that context has over this personal internal balance. In this way what they aimed to add to the body of knowledge is which personal factors are determinates for behavior change.

Edward L. Deci and Richard M. Ryan were also interested in what preceded behavior and so created the *Self-Determination Theory (SDT)* describing three different kinds of motivation. These three kinds of motivation are based on three innate needs people have; that of relatedness, competence and autonomy. People's need for relatedness is reciprocal and describes the need to belong and feel an emotional bond with other so that they care about the individual and the individual cares about them. Competence refers to people's need to feel that they are capable and able. Thirdly people have the need to feel they have the freedom to make choices so they can support their actions as a matter of their own choice. This need to agency over their lives and situation, is referred to as autonomy within the SDT (Ryan and Deci 2000). The SDT states that motivation can either stem from within themselves for tasks that are intrinsically satisfying, called autonomous motivation, or it can stem from aligning a task with the individual's internal motivation, sometimes called identified motivation. Identified motivation is led by external consequences, such as punishment and reward, or by feelings of appreciation of rejection, referred to as introjected motivation. In either case the individual takes to an action or task because the it answers the need of the three kinds of motivation, relatedness, competence and autonomy.

Like the above-mentioned authors, Bandura seemed to be looking for traits or factors which inform or determine behavior change, yet Bandura examines how past experiences of the individual can affect propensity to undertake a behavior in the future. *Self-efficacy* is possibly the most widely acknowledged factor contributing or determining behavior change. The Self Efficacy theory explains that self-efficacy is an important determining factor towards the performance of any behavior. Self-efficacy is a self-evaluation terming one's belief that they are able to successfully execute a behavior in order to produce a desired outcome (Bandura 1977; Lee et al. 2008). It is believed that an individual's level of self-efficacy is indicative of the amount of effort they will put into performing and maintaining the target behavior. If an individual has had success undertaking similar challenges, i.e. losing weight or adopting a new exercise routine, they will be more likely to put in the time and effort

to pursue related target behaviors. In contrast, if an individual has the experience that they are usually not successful at maintaining similar kinds of goals to the target behavior, they are more likely to disengage with action towards that behavior. Thus, in order to understand how people, adopt new target behaviors we also have to understand their self-efficacy in relation to the attempted behavior change.

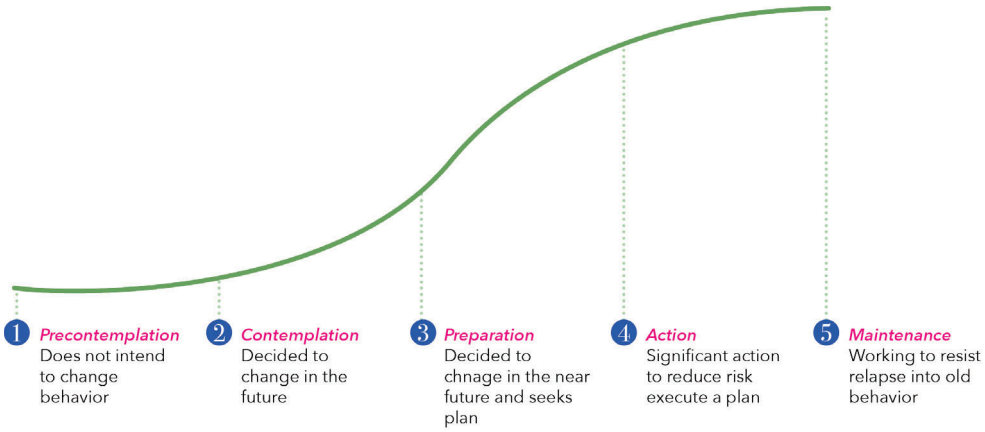


Figure 1: The Transtheoretical Model of Behavior Change (TTM) stages of change

Beyond the factors related or indicative of behavior change the *transtheoretical model of behavior change (TTM)* aims to describe the process of behavior change (Prochaska and Velicer 1997). The TTM seeks to describe behavior change as a dynamic process in which the attitude of the individual changes overtime in relation to the target behavior (Prochaska and Velicer 1997), Figure 1. The six different stages of the TTM an individual must move though in order to effect behavior change, is the reason this model is often referred to as the stage of change model, Figure 1. The precontemplation stage is the first stage the TTM describes. Individuals in this stage do not intend to change, either because they are under- or un-informed about their undesirable behavior, or because they have been unsuccessful at changing a specific behavior in the past so that they gave up trying. In this first stage we could describe an individual as being unmotivated or even resistant to change (Prochaska and Velicer 1997). Contemplation is the second stage of change, here an individual has accepted that change in desirable yet has not yet undertaken any steps to change their behavior. Prochaska and Velicer explain that in this stage individuals weigh the pains from changing with the gains from their improved behavior. This can lead them

to get stuck in this stage, never finding the right time to exert the effort needed to change which can lead to behavioral procrastination. When individuals move from the contemplation phase to the preparation phase they decide to change in the immediate future and have a plan of action to achieve this change. The next is the action stage and is defined by a modification in behavior which a professional of a related field would agree is significant enough to reduce risk factors. In this way, the TTM does not recognize changes in behavior which are so small they will not yield the benefits associated with the target behavior. In the maintenance stage, individuals cease to rely on change processes like in the action stage yet are working to resist relapse of their old behavior. The maintenance phase can last anywhere from one month to five years and only concludes when the individual does not run the risk of regression (the return to an earlier stage of change) and only then will an individual have reached the rumination stage. Prochaska and Velicer worn that not many people ever truly make it to the termination stage so that the maintenance becomes the enduring end stage of the journey where many still struggle with their former habits for a long time.

Along with the description on each of these six consecutive stages of change, Prochaska and Velicer describe ten kinds of activities, or processes of change, to support behavior change, described in Table 2. For example, 'Consciousness raising' refers to informing individuals about the effects of their behavior. 'Dramatic relief' is the process of working on an individual's emotions until they change their behavior, or 'do the right thing', to give themselves relief from their emotional anxiety. It is clear that depending on the stage of change an individual could benefit from different processes of change mentioned by Prochaska and Velicer. Understanding in which stage of change an individual is regarding their attitude toward change, is very important as it can inform which kinds(s) of activities might support the desired behavior change.

TABLE 2: ACTIVITIES TO SUPPORT BEHAVIOR CHANGE

PROCESS OF CHANGE	DEFINITION / EXPLANATION
CONSCIOUSNESS RAISING	Education, raising awareness on the benefits and risk factors associated with current and target behavior
DRAMATIC RELIEF	Drawing on an individual's emotions to 'do the right thing', this action gives them relief from the anxiety
SELF-REVELATION	Assessment of one's self image, with and without undesired behavior and new welcome behavior. Think healthy role models and value clarification
ENVIRONMENTAL RE-EVALUATION	What kind of a role model are you with this bad habit to your kids?
SELF-LIBERATION	This is the belief that you can change. So really just will power. An interesting note here is that psychology shows that people with two choices are more committed to their choice then people with only one option and people with more than two options are even more motivated for their choice than the people who only had two option. What does this science say about my career choices in the past and how happy each one has made me?
SOCIAL LIBERATION	Increase in social opportunities. Think smoke free zones and salad bars in school lunchrooms.
COUNTERCONDITIONING	Substitute the problem behavior with healthier behavior. Substitute relaxation for stress and fruit smoothies for sugary soda.
STIMULUS CONTROL	"removes cues for unhealthy habits and adds prompts for healthier alternatives" like "environmental reengineering" placing the parking lot 2 min away from the office buildings for example
CONTINGENCY MANAGEMENT	Structure of reward and punishment that can guide the individual in the right direction.
HELPING RELATIONSHIPS	A support system. I feel the aa probably relies on this principle.

Though the above discussed theories identify certain factors thought to be important to behavior change, such as stage of change, kind of motivation and level of self-efficacy, other experts in the field have contributed models which further explain why a change in behavior comes about. In the next section we will look at theories based around the assertion of expectancy value.

Rational Choice Theories and Models

Beyond theories which describe behavior change, there are many authors who aim to explain not the how, of the behavior change process, but additionally why an individual engages in a certain behavior. The theories in this section largely relate or are built off of the expectancy value theory.

The *Expectancy Value theory* was a fundamental theory which asserts that behaviors are the result of careful contemplation on the beliefs an individual has about a certain subject or action as well as it's perceived value to that person. In essence this theory states that people perform behaviors based on rational consideration and a certain cost-benefit analysis. This would be the foundation of several rational choice theories, such as the *theory of reasoned action*, the *theory of planned behavior*, the *protection motivation theory*, and the *health belief model*.

The *theory of reasoned action* built on the expectancy value theory and was originally developed in 1967 by Martin Fishbein (Fishbein 2008). It explained behavior as a result of attitudes one holds about an object or action. Fishbein considered intention to be determined by a balance of perceived norms about a behavior and the individual's attitude toward that behavior. He considered actual behavior to be the direct result of intention, Figure 2: The Theory of Reasoned Action. Shortly after the conceptualization of this theory Fishbein collaborated with Icek Ajzen to expand the theory of reasoned action into the theory of planned behavior, Figure 3. The *theory of planned behavior* describes the performance of a particular behavior to be proportionate to both the amount of control over this performance and the strength of this individual's intention to perform that behavior. The key difference between the two theories is that the theory of planned behavior added perceived behavioral control to intention as key determinates of behavior. Perceived behavioral control refers to the individual's perception of their control over if they will be able to execute the behavior in question. This construct differs from that of self-efficacy in that, though they both measure perceived ability to successfully perform a behavior, the perceived behavioral controls mostly measures the perceived difficulty of performing the behavior whereas self-efficacy is used to refer to the individual's belief in their personal ability to execute a behavior. The theory of planned behavior takes factors outside a person's control in to account as these might drive or inhibit an individual's performance of a particular planned behavior. Yet both the theory of reasoned action and the theory of planned behavior focus heavily on intention as the main precursor

to action, and though many would agree that intention is important to action, it has also been shown that intention is not indicative of action. Even people with the best intentions fall short of their behavior goals.

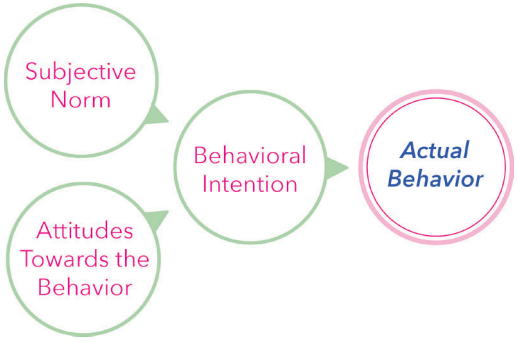


Figure 2: The Theory of Reasoned Action

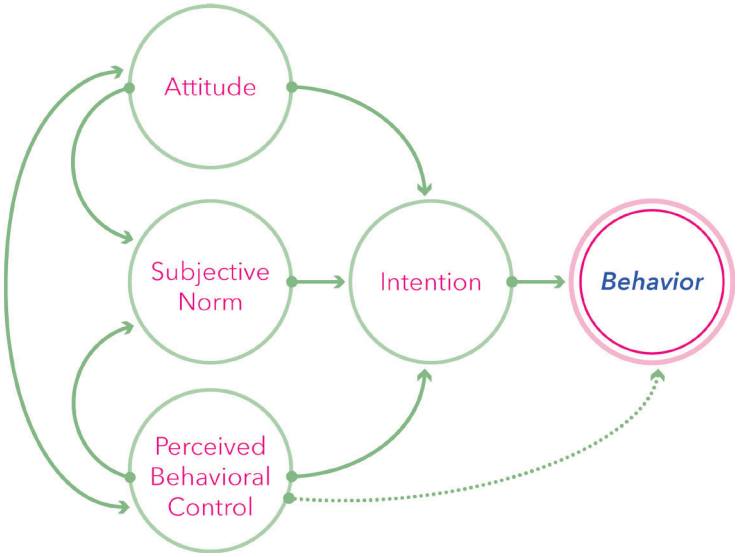


Figure 3: The Theory of Planned Behavior

The *protection motivation theory* is also firmly based in the notion that behavior is a result of cognitive evaluation, only it was originally used to clarify how fear appeals work, Figure 4. As with the subjective norm and attitude towards the given behavior, in this theory a perceived threat (consisting of the perceived susceptibility and the severity) and coping (consisting of one's perceive self- and response-efficacy) are weighed to determine the extent of one's protection motivation which, according to this theory, is a direct determinate to action or coping response. This theory can explain why telling a customer who is considering a purchase, "this is the last one in your size so if you come back tomorrow it might be gone", will often spur the customer to purchase that item. This tactic appeals to the protection motivation mechanism as the customer weighs the susceptibility of the threat (what is the likelihood someone else will come and buy this dress this afternoon?), the perceived severity (if I come back tomorrow and this item is gone, how disappointed will I be?) against the coping appraisal (what does it take for me to purchase this item or pursue this goal and can I do it?).

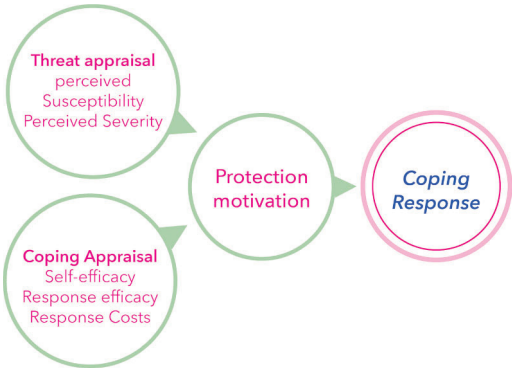


Figure 4: The Protection Motivation Theory

Compared to the theory of reasoned action, planned behavior and the protection motivation theory, the *health belief model* is more complete in that it takes a more holistic view of the factors which influence action, Figure 5. Like the theory of planned behavior, the health belief model sees that action is in part determined by the individual's perception of their ability to control the situation or the balance of benefits and barriers (Skinner et al. 2015). Like the protection motivation theory, the health belief theory, shows that people need to weigh their perceived threat like susceptibility and severity with the perceived effectiveness of treatment and their own ability to accomplish the necessary tasks to address the behavior in question. Unlike the theory of planned behavior and theory of reasoned action, the health

belief model acknowledges that demographic and psychological characteristics will influence the way in which people perceive threats like susceptibility and severity, benefits and barriers and determine their health motivation, the extent to which they are motivated to peruse healthy behavior and habits, all of which determine if an action is taken or not, according to the Health belief model. In addition, this model acknowledges that external cues like reminders can play a part in determining if a specific action is done. However, though is model is more all-encompassing than the previous two theories, by acknowledging the effect of the personal factors such as psychological and demographic factors, it does not treat context as a determining factor in action except for the mention of cues. Yet, context can contribute more in the way of determining factors than cues alone. For example, poor local facilities are often cited as barriers preventing people in urban settings to engage in outside physical activities like running when there is no park nearby. In essence, this model shows that people balance risks and likelihoods, and benefits and barriers in order to come to a conclusion about whether or not to undertake an action.

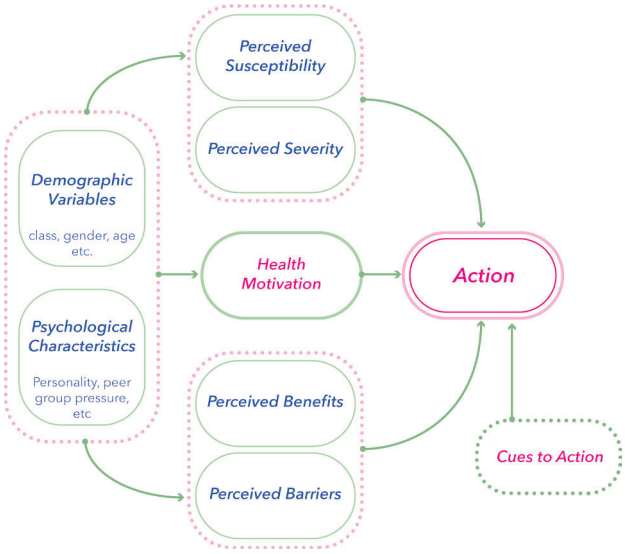


Figure 5: The Health Belief Model

The rational choice theories fundamentally see the intention toward behavior resulting from considerations of cost and benefits as a natural precursor to behavior. Though as simple fundamental theories these theories are informative, they lack the comprehensive overview of the different kinds of factors which can determine behavior. In the next section, we will discuss the learning theories, these theories determine that intention or a considered decision on the topic of an action, are not necessarily indicative towards action or behavior.

Learning Theories

Where the rational choice theories or value expectancy theories saw action as the direct result of intention through consideration, the learning theories see behavior as a function of one's perception of the potential outcome of an action and their own ability to accomplish the action (Lee et al. 2008). In addition, learning theories acknowledge the influence of an individual's context. The division of these two groups is nuanced as both camps have some overlapping understanding of factors that influence behavior yet, this section of the related works section was divided up in this way to highlight the gradual development of theories and models that are more holistic in their inclusion of factors that influence/determine behavior.

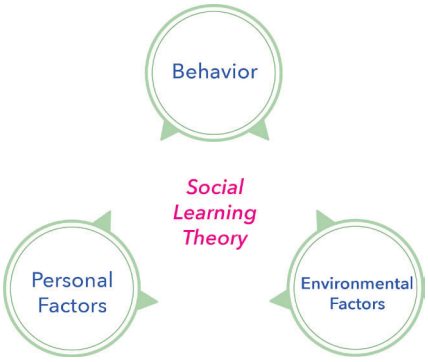


Figure 6: The Social Learning Theory

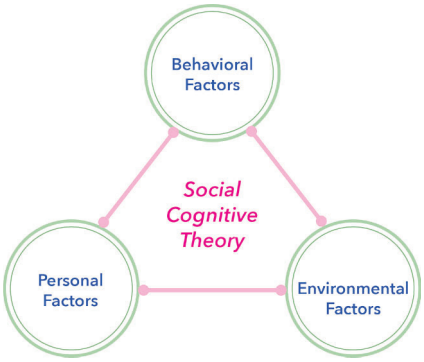


Figure 7: The Social Cognitive Theory

Learning theories, in essence, are built on the notion that behavior change is the product of environmental, personal and behavioral aspects all interrelated to affect an individual's behavior. As such the *social learning theory* (Bandura 1971), Figure 6, later developed into the *social cognitive theory (SCT)* (Bandura 1999), Figure 7, talks about the interrelatedness of these three aspects and how an individual's behavior is driven by their characteristics which are in part a result of their environment. These learning theories present the notion that people learn behavior from one another and even adopt new habits through observing others, referred to as observational learning. In essence it acknowledges that people do not perform behaviors in a vacuum but rather amidst ever present social and situational contexts. Unlike the other more linear systems previously described, the SCT is referred to as triadic reciprocal determinism, in which behavior personal and environmental factors all have influence over one another.

TABLE 3: BEHAVIORAL DETERMINATE FACTORS FORM THE SOCIAL COGNITIVE THEORY

BEHAVIORAL CAPABILITY	One's ability to perform the behavior pertaining to both knowledge and skills
REINFORCEMENTS	Consequences of behavior, often from the environment, which can be positive or negative and affect the likelihood of a behavior
EXPECTATIONS	Anticipated consequences of behavior, largely founded on experience
SELF-EFFICACY	Affected by facilitators, barriers, personal capabilities and other individual factors, self-efficacy is a person's perception of their own ability to successfully preform a given behavior

The SCT presents certain important factors contributing to behavior regulation, Table 3. These factors provide insight into what affects, and ultimately, determines behavior, beyond the rational choices some would assume behavior to be. The learning theories teach us that an individual's behavior is subject to the effects of their environment, their own confidence in their ability to perform a task, their experience with like behaviors and the influence of observing others performing like behaviors. There is a lot that goes into observing and understanding the mechanisms at work to bring about behavior change. Yet the question remains how can the factors mentioned above be used rather than just observed, in order to facilitate behavior change? In the next section we will examine models which take a more practical approach, and which make suggestions on how to actively promote behavior change.

Actionable Behavior Change Strategies

Though the previously mentioned theories and models attempted to describe the elements that contribute to behavior change and the process of change, other authors have aimed to contribute insight into how to activate behavior change. This section is particularly relevant as it presents strategies which may be used in the design of behavior change solutions for older adults which aim to stimulate increased physical activity.

As such, B.J. Fogg aimed to explain the determining factors of action in terms of behavior change. His fundamental model, the *Fogg Behavior Model (FBM*) (Fogg 2009), maps the threshold of action to have an inverse relationship between motivation and ability, Figure 8: Fogg's Behavior Model. In this model behavior is described as

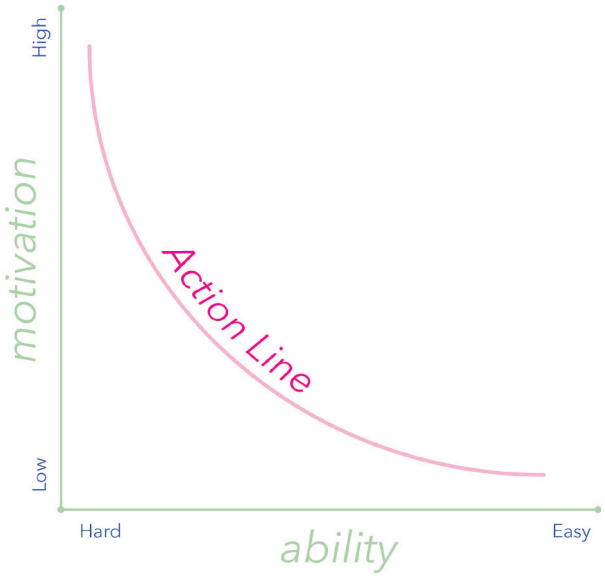


Figure 8: Fogg's Behavior Model

a result of three different factors; motivation, ability and triggers. In Fogg's simple behavior change model, he indicates that action is the result of a function between ability and motivation. According to Fogg action, motivation, ability and triggers are each important elements which drive behavior, described in more detail in Table 4: Fogg's three factors necessary for behavior change defined. In his graph, depicted in Figure 8, we can clearly see that the more ability an action requires (whether this is ability in terms of time, monitory expense or mental investment does not matter) the higher an individual's motivation needs to be to cross the 'action line' when exposed to a trigger. Fogg's action line describes the minimum level of motivation in relation to ability a user needs to have in order to respond positively to triggers. If the individual is motivated but does not have the ability to complete a task even a well-timed trigger will not move them to perform the task successfully. Conversely, if a task is easy to do but there is very little to no motivation to do it then still there will be no change in behavior. Only when motivation is balanced with the amount of ability needed for an action can a trigger instigate an action.

TABLE 4: FOGG'S THREE FACTORS NECESSARY FOR BEHAVIOR CHANGE DEFINED

TRIGGER	Without being triggered to action it is unlikely that a person will change their behavior. Fogg explains that triggers can take many forms, and can serve to spark, facilitate or signal towards the completion of a desired behavior. A successful trigger is noticeable, associated with the desired behavior and well-timed, ideally when a person has the motivation and ability to perform the desired (Fogg 2009). A trigger to remind ourselves to return a library book is no good if we do not notice the note, we left ourselves until we have already left the house without it or if we can't remember why we tied a string around our finger in the first place.
MOTIVATION	Fogg divides his motivation factor into three distinct "motivators"; Pain and Pleasure, Hope and Fear, and social acceptance and Rejection. The aversion or the threat of pain, fear, and/or rejection motivate people depending on the threat perceived.
ABILITY	Often physical effort is the first element of ability which spring to mind, together with time and money. Yet ability comes in many different forms; money, time, physical effort, brain cycles, social deviances and non-routine. The first three are pretty self-explanatory. Brain cycles refers to the amount of mental effort required. When a behavior deviates from the social norm it can also lower owns ability to perform this behavior as there are social deviances resisting it. Even deviating from behavior that has become a routine can lower one's ability to perform the new behavior as it can be difficult to overcome this non-routine (Fogg 2009).

Beyond theories which describe the process of behavior change Fogg attempts to understand the determinates which cause behavior change, by describing necessary triggers and looking at an individual's motivation and ability to perform a certain behavior, Figure 9: Fogg's three factors. In this way, Fogg makes practical suggestions to address each of these three important factors to optimize the chance of change. For designers of behavior change systems it is thus important to be able to anticipate not only which kind of trigger is most helpful to spur a targeted behavior but the appropriate timing of this trigger. In addition, designers of behavior change systems should understand what motivates the user, so that if there is a lack of motivation, they can address that, for example with messages that support motivation. In terms of ability, each person has a different 'simplicity profile', as some have more money and some more time. This may also vary depending on context, like day of the week, or at home versus at work. It is therefore important for designers to understand the individual situations of those who will use the behavior change intervention. Understanding the kind of ability required, and the kind/extent of motivation present can help designers of behavior change interventions balance these necessary factors towards behavior change either by aiming to increase the motivation for the desired behavior or by

designing systems which lower the ability necessary to complete the desired behavior. From these practical insights into designing systems and interventions for behavior change Fogg presents, in essence a rather actionable three-step process for design behavior change:

- Step 1: "Translate target outcomes and goals into behaviors."
- Step 2: "make it easy"
- Step 3: "what will prompt the behavior"

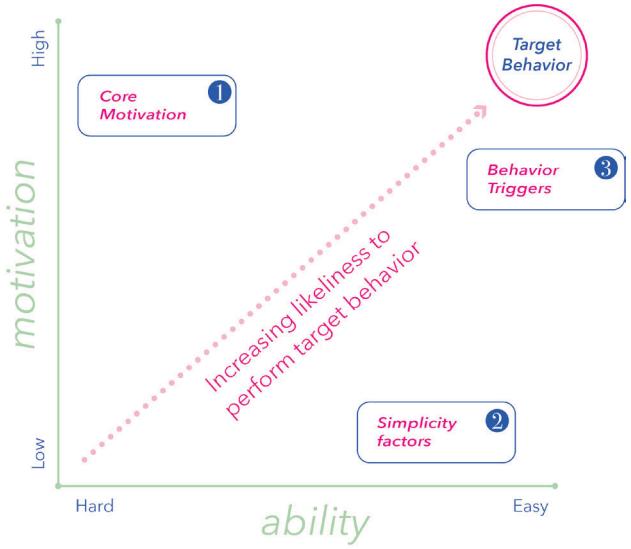


Figure 9: Fogg's three factors

Though Fogg presents many useful elements important to behavior change to keep in mind, he does not go into depth to provide us with choices of clear strategies to implement the mechanisms responsible for activating a change in behavior. Harri Oinas-Kukkonen's *persuasive systems design (PSD)*, describes how persuasive systems are developed by first, understanding issues behind behavior change, analyzing the persuasion context and then design system qualities (Oinas-kukkonen and Harjumaa 2009). The context Oinas-Kukkonen mentions refers to the intent, event and strategy of the persuasion. The PSD examines four system qualities, primary task support, dialog support, system credibility, and social support, for designers to utilize when aiming at targeted behavior change (Oinas-kukkonen and Harjumaa 2009), Table 5. Each of these qualities is further detailed

into several principles, which each offer very practical application suggestion to support behavior change. These system qualities can be applied to inspire design for behavior change and have inspired a card set which acts as a brainstorming tool (Ren et al. 2017). Ostensibly Oinas-Kukkonen's principles offer strategies to design the triggers for behavior change. Though on their own these strategies seem to focus on implementation, it could be interesting to combine it with the practical strategies suggested by Oinas-Kukkonen with the more psychologically founded literature of the previous sections.

TABLE 5: THE FOUR PERSUASIVE DESIGN SYSTEM QUALITIES EXPLAINED

PRIMARY TASK SUPPORT	Supports the user in carrying out their goal behavior or primary task
DIALOG SUPPORT	Refers to computer to human dialog often in the form of some sort of feedback received from the system
SYSTEM CREDIBILITY SUPPORT	Helps the designer design a system which is perceived as more credible to the user and therefore more persuasive
SOCIAL SUPPORT	Leverages social influence to motivate users sometimes through connecting different users

Like the PSD model, Michie's *Behavior Change Wheel (BCW)* also offers implementable strategies for behavior change. The BCW is based on the *Capability Opportunity Motivation Behavior (COM-B) model*, (2014), which is a central element of the larger BCW framework. The COM-B's main premise is that an individual needs to have the capability, opportunity and the motivation to perform a task or target behavior. To some extent this resonates with Fogg's ideas on the factors necessary to result in behavior being motivation, ability and a well-timed trigger, if we draw a parallel between capability and opportunity and between opportunity and a well-timed trigger. Of course, opportunity is a much larger concept than just a trigger. Opportunity consists of both physical opportunities, pertaining to the environmental context and social opportunities, pertaining to social and cultural norms. Capability consist of both psychological understanding around the subject and the physical capability such as having the physical skills to perform a task. Motivation also consist of both reflective motivations, referring to one's thoughts and beliefs and automatic motivation referring to impulses and habits, as shown in Table 6. Above all the COM-B Model provides us with a framework in which to place user insights when collecting information on the target audience of the intended behavior change.

TABLE 6: THE COM-B MODEL

CAPABILITY	*PHYCOLOGICAL*	Understanding around the subject	Ex: Knowing that takeout usually has more salt than home cooked foods
	PHYSICAL	Physical skill	Ex: Having the skills to cook, and perform necessary tasks like cutting vegetables
OPPORTUNITY	*PHYSICAL*	Environmental context	Ex: Availability of fresh food markets or a kitchen to cook in
	SOCIAL	Social and cultural norms	Ex: Social acceptability of eating lunch from home in your company culture
MOTIVATION	*REFLECTIVE*	Thoughts and beliefs	Ex: Awareness of heart health and cholesterol levels. Confidence in the success of diet related prevention
	AUTOMATIC	Wants, needs, impulses and habits	Ex: Cravings for deliciously salty takeout foods

The COM-B model sits at the center of the Behavior Change Wheel (Michie et al. 2011), which can be seen as a process to developing theory drive health behavior change interventions more so than a model of behavior change. In the first stage of this process designers of behavior change interventions are encouraged to understand the behavior they would like to change and define very specifically how, when, where the target behavior should be performed, using the COM-B Model (Michie et al. 2011).

In the next stage of the process, intervention functions appropriate to address the COM-B components should be identified, before identifying appropriate policy categories. Figure 10: The Intervention Functions Matrix Tool shows there are 9 intervention functions such as education, restriction, and modeling. The policy matrix tool suggests which policy categories, such as marketing, legislation and service provision, are applicable for the intervention functions. The policy matrix tool, Figure 11, lets us know which intervention functions could be delivered in which medium or policy category. For example, they suggest using communication/ marketing to educate the audience.

In the final stage of the process, the focus is on identifying content. For each intervention function there are many behavior change techniques, outlined in the behavior change wheel book. For this model, Michie et al. (2011), identified intervention categories from 19 existing frameworks. Once the behavior change techniques are chosen, the final step in this process to develop behavior change interventions is to identify a mode of delivery, whether a poster campaign or a mobile application, which will evoke the target behavior.

COM-B Components	Intervention Function								
	Education	Persuasion	Incentivization	Coercion	Training	Restriction	Environmental Restructuring	Modelling	Enablement
Psychological capability									
Physical capability									
Physical opportunity									
Social opportunity									
Automatic motivation									
Reflective motivation									

Figure 10: The Intervention Functions Matrix Tool

Policy Categories	Intervention Function								
	Education	Persuasion	Incentivization	Coercion	Training	Restriction	Environmental Restructuring	Modelling	Enablement
Communication / Marketing	■	■	■	■				■	
Guidelines	■	■	■	■	■	■	■		■
Fiscal measures			■	■	■		■		■
Regulation	■	■	■	■	■	■	■		■
Legislation	■	■	■	■	■	■	■		■
Environment/ Social Planning							■		■
Service provision	■	■	■	■	■			■	■

Figure 11: The Policy Matrix Tool

What the Fogg Model, PSD and BCW have in common is that they provide practical guidelines as to how to design behavior change interventions to motivate people to adopt healthier habits. Many of the theories and strategies discussed here link personal traits or factors to behavior change. From this it is clear that interventions aimed at instigating behavior change should be personalized to fit the user and context of

use. Experts agree that personalization increases the effectiveness of the behavior change solutions (Bull, Kreuter, and Scharff 1999; Cabrita et al. 2015; Campbell et al. 1994; Purpura et al. 2011; Schutzer and Graves 2004). Furthermore, there is strong evidence that this need for personalization is even more important when designing for older adult users (Cabrita et al. 2015; LeRouge et al. 2011). In order to support this diverse group's increased engagement with physical activity, behavior change solutions need to be personalized to appropriately address their needs. Yet there is little knowledge about which specific combination of promising factors should be used to profile older adults for use in choosing appropriate behavior change strategies.

In addition, bespoke or custom solutions highly personalized to the individual are practically impossible to provide on a large scale and are very costly to develop. Current automized personalization methods, such as purchase recommendary systems used in online marketing or in-app goal setting due to previous activity levels, lack the necessary contextual and psychological depth beyond measured activity data or other measured physiological data (Kaptein, Markopoulos, et al. 2015). Behavior change experts advocate that using user profiles can provide the necessary middle ground between the inadvisable 'one size fits all' approach, while streamlining the creation of these behavior change solutions by avoiding custom interventions (Friederichs et al. 2015; Hardcastle and Hagger 2016; Kaptein, Markopoulos, et al. 2015; LeRouge et al. 2011; Looman et al. 2018).

A variety of models and strategies can be applied to the challenge of motivating behavior change among older adults towards a healthier and more active lifestyle. However, it is clear that, though there is a need for more research into the relevant personal factors, personalization is an important aspect of successful behavior change solutions. In the next section we will address what role technology can play in aiding the personalization of these important behavior change interventions.

Personalization Towards Behavior Change: Technology's Potential

There is a growing need for personalized behavior change interventions which stimulate increased physical activity among older adults. Mobile and digital technologies offer the potential to create personalize-able solutions to motivate increased physical activity to scale, thus there is an important need to develop these valuable new technologies.

In recent years new wearable sensing and monitoring technologies have allowed users to gain more insight into their health through continuous measurement. In a systematic review of 26 articles about the viability of smartphone use for measuring and influencing physical activity, Bort-Roig et al. found that these articles reported generally positive accuracy measurements, novel diversity and users' impression of usability, illustrate the potential wearable technologies have to promote physical activity (Bort-Roig et al. 2014). Currently these technologies are enjoyed by runners and other exercise enthusiasts, by providing training and progress insights. Meanwhile wearable technologies are also being used to monitor sedentary behavior and stimulate more physical activity, among office workers. Market leaders like Fitbit, trust the wide-scale success and importance of the potential of these technologies to help people avoid a sedentary lifestyle. In fact, early research shows that intelligent technologies can offer opportunities to support older adults to adjust to aging while remaining healthy and active allowing them to stay in their private homes longer, commonly referred to as aging in place (Blaschke, Freddolino, and Mullen 2009). This independence is valuable, as studies show that many older adults prefer to continue living in their private home instead of moving to institutionalized care or a care home (van Hoof 2010). Vollmer Dahlke and Ory report that mobile applications have already been used for a variety of kinds of health promotion goals including increasing physical activity, to show that mobile technology for health promotion has the potential to be embraced by older adults, however the authors express the need for a better understanding of usability, accessibility, perceived benefit, and relevance to the older adult individuals specific socio-demographics (Vollmer Dahlke and Ory 2016). Though, mobile health applications already show potential to support healthy and active ageing, more research is required to adapt these developing technologies to make them appropriate to address the needs of older adults (Helbostad et al. 2017). It is hoped that the introduction of these technologies will have a positive effect in the amount of physical activity older adults do (Randriambelonoro et al. 2017).

While these wearable technologies can enable older adults to track their activity and other health indicators health about their physical wellbeing, this potential remains untapped for an important subset of older adults for whom the acceptance of these technologies is a challenge (Yusif, Soar, and Hafeez-Baig 2016). In fact, technology acceptance tends to be lower among people of advanced age (Charness and Boot 2009; Peek 2017). While 93% of Europeans aged 25 to 54 reported having used the internet in the last three months, for people aged 55 to 64 this was 73% and for people aged 65 to 74 this percentage was even lower; only 52% (EuroStat 2018). The older adult population is highly diverse in many aspects including level of technology acceptance and adoption. We need to find solutions for the subset of older adults who could benefit from these useful technologies, yet who face barriers preventing them from accepting and adopting these technologies.

One reason for the lack of adoption of these technologies could be due to the way the technologies are developed. Current off-the-shelf wearable sensors are generally not designed with the specific needs and barriers of this target audience in mind. Most of the off the shelf wearable activity trackers for instance are designed and marketed towards exercise enthusiasts of a younger generation. Besides a lack of experience with digital or wearable technologies, many new interventions do not adequately consider the mental and physical challenges some older adults may face when using this technology, such as decreased dexterity or lack of procedural knowledge (Holzinger, Searle, and Nischelwitzer 2007; Vollmer Dahlke and Ory 2016). Furthermore, the models commonly used to anticipate or encourage the adoption of new technologies have largely been based off of and created using study subjects who do not represent the older adult population, so that these models may only apply in part to the users and challenge at hand.

The *Technology Acceptance Model (TAM)* (Davis, Bagozzi, and Warshaw 1989) took into account the perceived usefulness and perceived ease of use, attitude toward technology use, behavioral intention and actual use, which is very relevant to older adults' adoption of technology. Older adults, like the MBA students in Davis's study (1989), need to believe that the ease of use of a technological intervention is proportionate to the added benefit they believe to gain from its use. To make the TAM more fitting to the domain of older adults, researchers have sought to include variables relating to older adult's biophysical and psychosocial needs. Venkatesh (Venkatesh and Davis 2000) proposed four determinants of technology acceptance (performance expectancy, effort expectancy, social influence, and facilitating conditions) and four key moderators (gender, age, voluntariness, and experience) in the *Unified Theory*

of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003). In this model, self-efficacy and anxiety are considered indirect determinants of intention mediated by, but distinct from effort expectancy or perceived ease of use (Venkatesh and Davis 2000). Chen and Chan (2011) added that personal traits and context, are also important to consider and might include the cost of the technology or the impact of decreased mobility on interaction with the technology as well (Chen and Chan 2011). Peek (2017) proposed therefore to include additional factors describing state-of-health, psychology, ability and specific challenge experienced by older adults (Peek 2017). However, to design for older adults with low technology acceptance, it is not enough to just evaluate the technologies according to the technology acceptance factors here discussed alone.

Though early models of technology acceptance have been developed further to address the unique needs and challenges older adults face, there is still a tendency to assume that if the interface meets basic usability requirements (for example related to color contrast, button and font size) that an interface or application will be adopted. In fact, sources indicate that designing technological interventions in such a way to make them acceptable to older adults unused to digital technologies is often not enough to result in the adoption, or regular use, of that intervention (Renaud and Biljon 2008). There is, in fact, a difference between technology acceptance and technology adoption (Renaud and Biljon 2008). Technology acceptance denotes more about the accepted ease of use of a system where technology adoption describes the behavior of using the technology and might be even more reflective of the perceived usefulness of a new technological intervention. The reason for this reluctance is that just because an application is usable for older adults does not mean it is relevant to their values, daily lives and routines.

A recent study shows that older adults and their adult children disagree about the use of in-home surveillance technologies (Berridge and Wetle 2020) indicating differences in certain values pertaining to the adoption of these technologies. Though this study found that among both older adults and their adult children privacy was a main concern, this paper calls for the development of shared decision-making tools to ensure the implementation of these technologies is consistent with older adults' values (Berridge and Wetle 2020). A literature review of 44 articles investigating older adults' adoption of assistive technologies revealed barriers to adoption arose when values such as privacy, trust, functionality, cost, sustainability and fear of dependence were not addressed (Yusif et al. 2016). Especially technologies perceived as stigmatizing invoked negative attitudes towards assistive technology acceptance

(Yusif et al. 2016). In fact one study found that not only did older adults carefully select current activities to project values important to them but that this projection of their personal values also translated into the products that they owned and used (Forlizzi, DiSalvo, and Gemperle 2004). Older adults were often found to have discerning tastes and their most important belongings tend to be those which support their feeling of identity, dignity and independence (Forlizzi et al. 2004). Though dignity and independence seem universally important to all people, perhaps they are even more relevant to those who feel that these values are threatened by limitations due to health problems or natural decline. In any case, older adults want to own and use products and services which are in line with these important values. Many older adults will go through great lengths to maintain a feeling of dignity and independence even if that means sacrificing some comforts, such as showering less to avoid the accessibility issues in the bathroom or not employing help for household cleaning tasks (Forlizzi et al. 2004). The relevance of these core values of the older participants of this study are manifested in their product choices. This is illustrated by product choices or actions like staying home, choosing to drive and desire to maintain particular personal standard in the home, making their own decisions and avoiding burdening their children (Forlizzi et al. 2004). It is therefore crucial to address the specific values of older adult users rather than only concentrating on usability needs to promote technology acceptance among older adults. To make sensing and monitoring interventions relevant to this audience, designers should empower these end users to collaborate on the design of interventions which support their independence.

Design for Behavior Change and Older Adults

To take full advantage of technology's potential to personalize behavior change solutions to support increased physical activity among older adults, we need to investigate ways to develop and test these technologies to address the older adult end user in valuable ways.

We envision that using a form of codesign process can facilitate the design of technologies to meet the needs and expectations of this older adult user group. Codesign processes aim to include end users in the development of these technological products and service systems. For example the participatory design process (PD), one form of codesign process, can empower end users to communicate their needs and values, and "respect people's democratic rights" (Iversen, Halskov, and Leong 2012), beyond just their physical restrictions (Davidson and Jensen 2013; Demirbilek 1999; Iversen et al. 2012; Lindsay et al. 2012). In this design approach the users' views and values are considered in the development of technology heavy interventions which will likely improve the acceptability of the technological solution proposed. Therefore the codesign process is particularly important to create interventions for older adult users with limited technology acceptance who experience barriers to technology acceptance. To take advantage of the potential technology offers in the domain of prolonged independent living, designers and developers of these innovative interventions have the responsibility to engage older adult end users in their design process to ensure that the needs and values of older adults are represented in the final product. Research is needed to examine how a codesign process can be used to support technology acceptance among older adults. Designing meaningful technologies for older adults to use remains a challenge because of the diverse needs and social-cultural contexts involved: not only on how to motivate the older adults to start to use the technologies (technology acceptance) but also on how to stimulate sustainable long-term usage (technology adoption). Though codesign processes are shown to be useful in developing behavior change technologies, there are only limited examples of studies where the codesign process is followed up by in-context testing or evaluation, so that few overall conclusions can be drawn about the technologies developed throughout these promising processes.

Beyond development, there is a need to evaluate these codesigned technologies and test developed interventions. Due to the dynamic nature of the behavior change process it is important to conduct research about behavior change in the context of use of the intervention. Often the behaviors in question cannot be simulated in a lab environment and nor could the complex web of naturally occurring facilitators and barriers to adoption of new behaviors. Thus, in-context behavior change research into how to motivate older adults to live healthy and active lives has become increasingly important, however there are few examples of this kind. Authors Wu Munteanu, 2018, write about a study they did in which they co-created and then field tested a fall risk assessment belt with older adults (Wu and Munteanu 2018). Yet they concede that their participants are likely not representative of the general older population as they were all experienced technology users. Despite the relative lack of examples of in-context behavior change research on this topic there is value in the use of living lab methods in behavior change research for the necessary in-context research. Hopfgartner et al. concluded that living labs can offer a more realistic view of how an intervention will be used (and possibly misused) in the user's regular day to day context, after showing that living lab studies and studies conducted in a laboratory setting had different outcomes (Hopfgartner et al. 2014). However, this work also mentions "various issues" that should to be addressed in order to facilitate living lab research (Hopfgartner et al. 2014).

Previous literature describes how to interact with participants and stakeholders during the test yet provides little clarity on how to design the setup of in-context study of technology intervention toward behavior change. More research needs to be done to investigate how codesign can be used to enable older adults to weigh in on the development of personalized behavior change technologies and on how to facilitate the in-context evaluation of these developed interventions.

The valuable work here presented, covers the several theories of behavior change, the stage of healthy aging in Europe, the potential of technology and certain guidelines on how to design behavior change solutions for older adults, yet it is still unclear how to effectively personalize behavior change strategies for use in technological behavior change solutions.

Though previous work, presented above, is valuable in its contribution, it fails to inform designers, how to personalize behavior change solutions aimed at motivating increased physical activity, for older adults. The literature suggests that the answer to this problem lies in a link between behavior change strategies and specific personal factors, which might be indicative of the user's response to behavior change strategy stimuli. Further the literature suggests that in order to design technology for older adult users, we should create opportunities to engage this diverse group of target users in the creation of these solutions while testing behavior change solutions should always be done in the context of use. We build on these helpful insights in order to investigate how we can effectively personalize behavior change solutions for older adults towards motivating increase physical activity and how we can help these target users engage in the research processed aimed at the development of these important technologies.

CHAPTER THREE

Objectives of this Thesis

From the literature reviewed, above, we know that there is a need to use technologies potential to personalize behavior change strategies to motivate older adults toward a more active lifestyle. Yet how these behavior change solutions should be developed is still less than clear. Thus, the main objective of this thesis is to address the following research questions:

RQ1: How can we effectively personalize behavior change solutions for community dwelling older adults to motivate increased physical activity towards a healthier lifestyle?

RQ2: How can we overcome the barriers to engage older adults in research related to technology development?

Towards addressing these research questions, in this work we focus on a subset of the very diverse older adult population who live in independent residences not in a care home or care facility, commonly referred to as community dwelling older adults. We collaborate with a local senior community center who aim, through various activities, to contribute to a more meaningful life for vulnerable older adults (ontmoet-en-groet.nl). Members of this senior community center have a Tilburg Frailty Index greater than 5 (Gobbens et al. 2010), which indicates they only have limited need for support, such as a walking aid, or some assistance with strenuous household tasks. Furthermore, though the possibilities in technology seem almost endless we focused on wearable and mobile technologies as these offered a practical and more affordable opportunities for monitoring the physical activity we were interested in as compared to options available for ambient sensors.

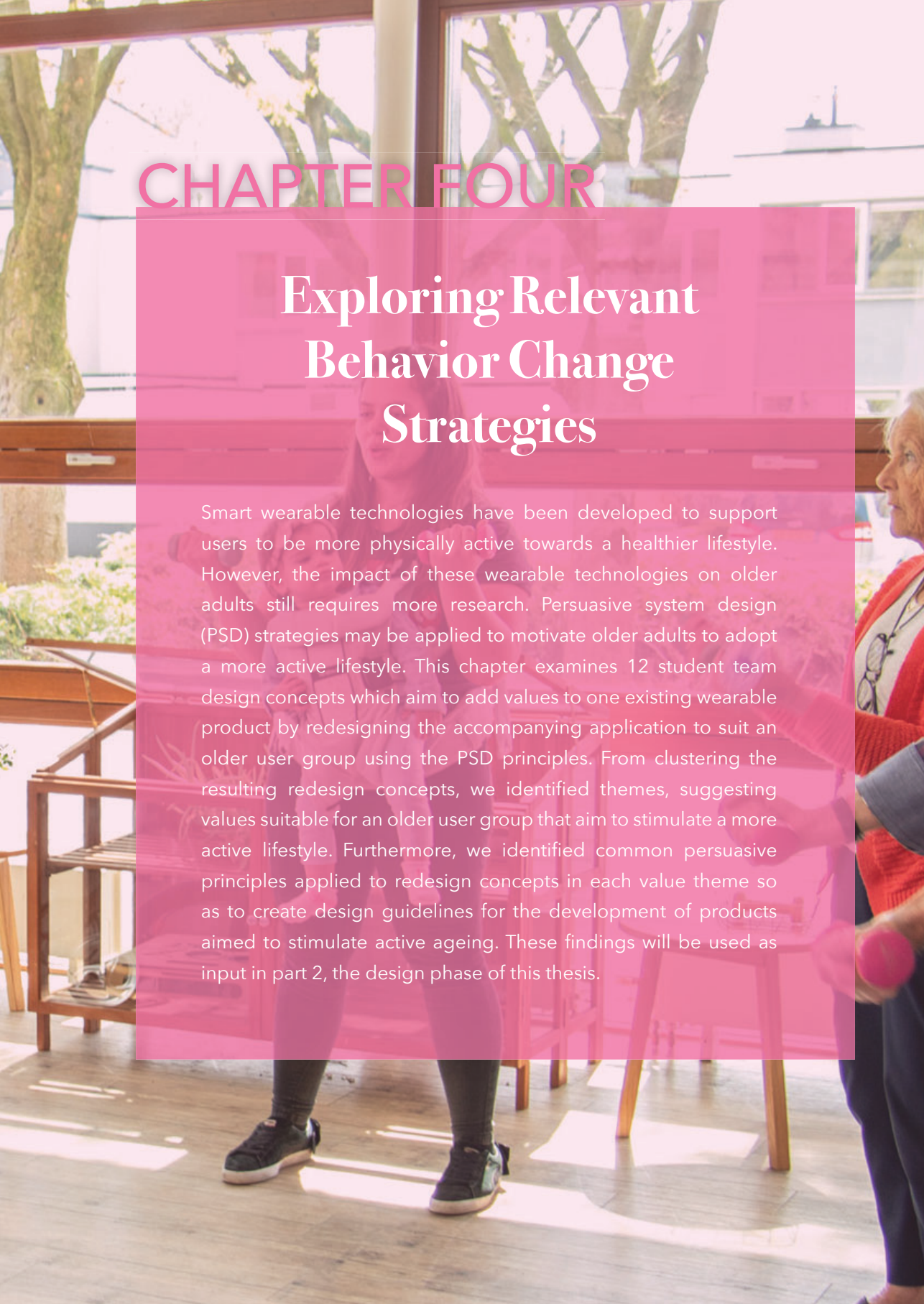
From the above research questions we can see that there are two levels of information contribution established here; there are procedural- and content-level knowledge. The procedural knowledge focuses on how to engage older adults to participate in the necessary in-context research while the content knowledge focuses on how a user's personal factors can inform which behavior change strategy is applicable. Due to the great number of behavior change strategies, we first needed to select certain strategies which held promise when applied to motivating older adults to be more physically active. From there we would explore how we could engage community dwelling older adults to participate in the necessary in-context research to create behavior change solutions. Finally, we could put this knowledge together in order to better understand which, if any, personal factors might indicate which behavior change strategy an individual would be more likely to respond to. In this way we can begin to create profiles of those older adult users to support designers to make better design decisions when creating behavior change solutions for this diverse group of people.

To answer our two overarching research questions, we will formulate this thesis in three parts, following our general design approach; 1. Exploration, 2. Design and 3. Evaluation. The studies and research investigations in each consecutive phase built on the works conducted in the last and served to provide input for the next phase. In each phase of this research we used a mixed method approach in which qualitative data provided deeper insight into quantitative data collected. During the exploration phase (Part 1 of this thesis) we considered which behavior change strategies might be promising for older adults (chapter four), investigated personal factors which should be used to profile older adults towards personalization (chapter five) and reflected on how we can facilitate older users to overcome the barriers to technology acceptance we observed throughout the exploration process (chapter six). These reflections informed Part 2 of this thesis, the design phase where we describe how we created two mobile applications aimed at motivating increased physical activity (chapter seven). For the evaluation phase of our research, Part 3 of this thesis, we built a product service system to engage older adults in research toward the development of technology-based behavior change solutions and assessed whether the system we created supported research engagement in in-context research towards behavior change technology development (chapter eight). In our final study (chapter nine) we evaluated what effect the two mobile applications, created in the design phase, had on participant's physical activity. From this, in-context evaluation, we were able to make suggestions on how certain profiles, created from a combination of personal factors, could indicate which behavior change strategy could be applied more effectively. Each chapter will discuss the research process relevant to that study in more detail, yet we feel it is worth mentioning here that in each investigation we strove to maintain the high level of ethical standards by maintaining close communication with knowledgeable parties on the subject from both the university and the senior community center while adhering to the EU horizon project 2020 guidelines (European Commission 2018b, 2018a).

Part Two

EXPLORE

During the exploration phase we investigated behavior change strategies for older users, conducted a field study to examine personal traits indicative of activity and reflected on factors of technology acceptance. The first study aimed to indicate which behavior change strategies might be promising for older adults. The second study, a diary study using both cultural and technological probes, allowed us to examine which personal traits relate to physical activity as a first step towards identifying personal factors which can inform the personalization of behavior change solutions. In the final chapter of this section, we reflect on this same diary study to gain a better understanding of the barriers that older adults face to technology acceptance.



CHAPTER FOUR

Exploring Relevant Behavior Change Strategies

Smart wearable technologies have been developed to support users to be more physically active towards a healthier lifestyle. However, the impact of these wearable technologies on older adults still requires more research. Persuasive system design (PSD) strategies may be applied to motivate older adults to adopt a more active lifestyle. This chapter examines 12 student team design concepts which aim to add values to one existing wearable product by redesigning the accompanying application to suit an older user group using the PSD principles. From clustering the resulting redesign concepts, we identified themes, suggesting values suitable for an older user group that aim to stimulate a more active lifestyle. Furthermore, we identified common persuasive principles applied to redesign concepts in each value theme so as to create design guidelines for the development of products aimed to stimulate active ageing. These findings will be used as input in part 2, the design phase of this thesis.

This chapter is based off of work presented in

Valk, C. A. L., Lu, Y., Ren, X., Wintermans, M. C., Kraaijevanger, I. P., Steenbakkers, J. J. H., & Visser, V. J. J. (2017). Towards personalized persuasive strategies for active ageing. Gerontechnology, 16, 160-172. https://doi.org/10.4017/gt.2017.16.3.005.00

Introduction

Technological behavior change solutions have already been used to motivate increased physical activity among working aged adults. Yet there is still little known about which behavior change strategies might work for older adults. To better understand which strategies, have the most potential to motivate increased physical activity among older adults, it is clear we need to explore how we can implement persuasive strategies in technological behavior change solutions. Oinas-Kukkonen and Hajumaa (Oinas-kukkonen and Harjumaa 2009) provide clear persuasive strategies in their article, Persuasive Systems Design (PSD). They outline four main system qualities (Primary Task Support, Dialogue Support, System Credibility Support, and Social Support). Each of these principles is further divided into descriptive design principles, referred to as persuasive principles. These persuasive principles can be used to classify the motivational drivers behind products, which aim to change user behavior toward a healthier lifestyle. Here we are interested in how these persuasive principles can be applied to create motivational drivers to promote physical activities among older adults.

Earlier related work emerges a strong indication that the application of persuasive strategies should be personalized to improve the likelihood of the target behavior being adopted (Higgins 1997; Kaptein, Markopoulos, et al. 2015; LeRouge et al. 2011; Purpura et al. 2011). Though much is written on the need for personalizing persuasive messages to match the user's motivational and psychological profile, it is unclear how strategies for persuasive or motivational messages can be applied to suit the specific and personalized needs of the user. This personalization is particularly important for the diverse older adult population, due to their largely varying needs (Cabrita et al. 2015; Gregor and Zajicek 2002; LeRouge et al. 2011). Yet we do not have enough understanding of the varying needs of these users in such a way that it can inform design decisions (LeRouge et al. 2011). There is evidence to suggest the importance of considering the values of older adults when designing technologies for these end users (Berridge and Wetle 2020; Forlizzi et al. 2004; Yusif et al. 2016), thus investigating the importance of investigating values associated with motivating increased physical activity should be further investigated. This chapter will describe and discuss an initial study intended to generate design strategy suggestions for further research and aims to contribute to a better understanding of how to apply the personalization of persuasive strategies for behavior change, especially for older adults.

Previous work to facilitate behavior change targeted an already motivated audience, such as a running application for running enthusiasts, often depending on the intrinsic motivation of the user, making these interventions inappropriate for those yet unmotivated to adopt a healthier lifestyle (Campbell et al. 1994). An important subset of the growing population of sedentary older adults is not motivated to engage in enough regular physical activity, and thus likely requires a different approach to motivate them to move more. This calls for research actions to explore ways in which persuasive strategies can be applied to adapt existing products, intended for physically active younger adults, to stimulate older users to adopt a more active lifestyle.

Methodology

The aim of this first study in the exploration phase was to identify which behavior change strategies have potential to motivate increased physical activity among older adults. Due to the lack of activity promoting products specifically targeting an older audience, we decided to analyze student group design concepts rather than existing products. To this end, we asked 12 groups of design students to redesign one of two physical activity stimulating products with the aim of making their redesign more suited to older adults. Each student group used an iterative user centered design approach to redesign their assigned behavior change product. By analyzing which persuasive design principles students applied in their final redesign concepts to motivate older users to live more actively, we aimed to formulate new hypotheses and design research questions to inform the next steps of our research.

There are a great many behavior change strategies and tactics, so to make our analysis more focused and comprehensible, we used Oinas-Kukkonen and Hajumaa's Persuasive Systems Design (Oinas-kukkonen and Harjumaa 2009) as a framework for analyzing the resulting student projects. The design outcomes would be cluster based on the persuasive strategies outlined in Persuasive Systems Design (Oinas-kukkonen and Harjumaa 2009).

Student Design Groups

The setup of these design cases was achieved in a multidisciplinary Bachelor course for first and second-year students at the Eindhoven University of Technology. This course aimed to teach students different market research methods and identify design opportunities through actively working in predefined design cases. At the start of the 4-week course from 17 November 2016 until 12th December 2016, 78 students were divided into 12 multidisciplinary groups of five to seven students per group. Table 7: Student Design Group Distributions, below provides the group information and the related design case. The 12 student groups were evenly divided and assigned one of two predefined design cases:

- Design case one asked student design groups to redesign the accompanying application of the HealthSit, a smart sensor mat pictured in Figure 12, designed to prevent sedentary sitting behavior among office workers. The HealthSit was designed by Ren (Ren et al. 2016), at the Department of Industrial Design, Eindhoven University of Technology (TU/e), to allow office workers to self-monitor their sitting behavior. The HealthSit prototype consists of six pressure sensors incorporated into a felt mat, which registers the sitting posture (Ren et al. 2016).
- Design case two asked for a redesign of the 2016 Xiaomi Band's accompanying mobile application (Figure 13) to stimulate increased physical activity among older adult users. The Xiaomi Band is a wearable sensor facilitating self-monitoring with an accompanying mobile application.

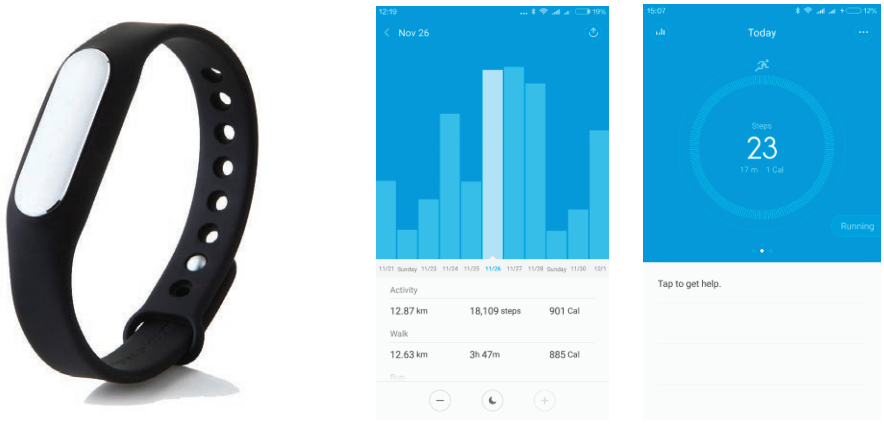


Figure 13: 2016 Xiaomi Band and screenshots of the accompanying mobile application (image source: (Tweakers 2017))

Figure 12: HealthSit active sitting sensor mat

TABLE 7: STUDENT DESIGN GROUP DISTRIBUTIONS

PRODUCT TO REDESIGN	*DESIGN FOR OLDER USER GROUP*
DESIGN CASE ONE SENSOR: HEALTHSIT	Group 7 with 7 students
	Group 8 with 7 students
	Group 9 with 6 students
	SGroup 16 with 7 students
	Group 17 with 7 students
	Group 18 with 6 students
	Subtotal number of students: 40 students
DESIGN CASE TWO *SENSOR: XIAOMI MI BAND*	Group 10 with 7 students
	Group 11 with 6 students
	Group 12 with 5 students
	Group 13 with 7 students
	Group 14 with 7 students
	Group 15 with 6 students
	Subtotal number of students: 38 students
TOTAL NUMBER OF STUDENTS	**78 students**

Student Team Design Process

Each student group followed a similar reflective transformative design process (Hummels and Frens 2009) and took on first, second and third person perspectives (Beukering 2014). All groups initially used the existing applications themselves, taking on the role of the user. After making some suggestions for redesign from their own perspective, all groups conducted semi-structured interviews with at least one older user. Older users never participated in user research with more than one student group for the duration of this design case. From their collected user insights, each of the twelve student groups then created a first design iteration for the redesign of their application. The groups got feedback on their design concepts from a second user interview or user test. Each of the student groups followed a comparable process for this design case.

Analyzing Resulting Design Concepts

In order to examine how persuasive strategies can be applied to adapt applications to more closely address the needs of sedentary older adults, the final concept video, presentation and report of each student group were collected and analyzed. The aim of this analysis was to specify how persuasive strategies could be applied to motivate the older adults to be more physically active.

To compare and analyze these concepts of this investigation, the general quality of each concept was examined in a user evaluation. Only concepts with sufficient quality were included in further analysis. We made a selection of a set of criteria, based on the 8 dimensions of product quality defined by Garvin (Garvin 1984), i.e., performance, feature, reliability, conformance, durability, serviceability, aesthetics, perceived quality, to evaluate the general quality of the concepts appropriate for this context. They determined that the concepts should be appealing to users (aesthetics), encourage physical activity (feature), stimulate continued usage (serviceability), allow room for personalization (feature), be realistic and accessible (serviceability). An independent focus group of potential future users (see Table 8: Focus group participants for more details) was asked to evaluate each concept based on criteria established by the authors. During the focus groups session, a

member of the research team presented concise descriptions of each concept and value proposition while displaying any visual material, like application screenshots or concept video the students provided in their deliverables, to the focus group. Focus group members were asked to rank their agreement with 9 statements related to the criteria specified by the authors. Assuming each of the statements bears equal weight on the quality of the concept we can examine the average of all 9 criteria and use this overall concept score to compare the quality of the concepts. All ratings are on the same Likert scale37 except statement 9 which uses an inverted Likert scale (Likert 1932). Therefore, the answers from statement 9 were inverted before calculating the average. Concepts with a higher than average score were considered to be of sufficient quality.

We analyzed these resulting student concepts further to identify the implemented persuasive principles through a careful examination of the submitted final reports, concept videos and presentation slides of the selected concepts. Each concept was also clustered according to the values that they created to promote physical activities. We then formulated hypotheses for future research based on the identified persuasive principles applied in each concept and their relation to the resulted values in order to get better understanding on how to create motivational strategies for promoting more physical activities among older adults.

TABLE 8: FOCUS GROUP PARTICIPANTS

PARTICIPANT NUMBER	*AGE*	*EDUCATION*	*NUMBER OF TIMES ENGAGED IN EXERCISE WEEKLY*
1	59	Masters	5
2	54	HBO[1]	2
3	61	PhD	3
4	56	MBO[1]	2

[1] Cooperation Organisation for Vocational Education, Training and the Labour Market (SBB). Vocational Education Labour Market 2017; https://www.s-bb.nl/en/education/dutch-educational-system/complete-description-dutch-educational-system; retrieved August 6, 2017

Results

Table 9 and Table 10, Summary of design concepts, summarize the final concepts and value propositions of each student group. Almost all student groups mentioned at one time the importance of translating the application into the native language of the seniors and using graphical interfaces suitable for seniors, such as easy to read text. These common observations were not discerned in the table below which reports on the student groups' unique concepts unless specific, explicit attention was paid to these elements in the final report.

TABLE 9: SUMMARY OF DESIGN CONCEPTS FOR MI BAND (NOTE: WHERE STUDENT GROUPS DID NOT NAME THEIR CONCEPTS, A TITLE WAS PROVIDED BY THE AUTHORS)

STUDENT GROUP	DESCRIPTION OF FINAL DESIGN CONCEPT	VALUE
Group 10: Profiling "My Mi Band and Me"	This application is highly personalized to the user. This system collects user data about physical activity during an introduction period of several days. The user also completes a survey to provide more information about their social contact and motivation style. Users are profiled according to their preference for social interventions against current level of physical activity. The system uses this profile to personalize messages including suggestions, social comparisons, and goal setting.	The user receives suggestions and goals that are highly personalized for them. Personalized goals and suggestions can support user self-awareness. Through the suggestions the user can enjoy social activities with other users.
Group 11: Public Dashboard	This concept consists of a large dashboard screen hung in the common space of the care home on which users can see their own and other resident's physical activity, which is translated into fun comparisons to bring the achievement in perspective (example: "today you have walked the length of the Rotterdam harbor"). The system offers nurses of the care home an easy overview to gain insight into how each resident is moving and sleeping. For more detailed information the system will collect and analyze resident behavioral patterns.	Older users can reflect their physical activity and enjoy their achievements together with others in a social setting. Users can also expect improved from more informed care professionals.
Group 12: Social Map	This application displays a map locating other users which allows the user to find, invite and challenge other users to engage in physical activity together. Third party companies may also implement sponsored locations or coupons to motivate users to plan/take part in activities.	Users can find friends to join activities. They may also receive discounts from local cafes and museums.
Group 13: User friendly goal setting	In this concept, personalized goal setting takes the user's mood into account by allowing the user to log their mood. This concept facilitates weekly goal setting based on personal attributes like weight, height, etc. The system allows the user insight into their activity and sleep log. In this group, particular attention was paid to ease of installation process and color scheme.	Users receive more attainable, suitable goals. Users can also look back and track their progress gaining more insight into the history and progress of their physical activity.
Group 14: Social scoreboard	This concept paid particular attention to information design and hierarchy to improve the ease of use for the user. A social score board in this concept allows users to compare their activity with other users in a competitive way. Push notifications vary from tailored statistic updates and motivational messages.	The user gets to compete with friends and acquaintances. In addition, users receive motivational messages that speak to his/her motivation.
Group 15: Physical activity planner	This concept's physical activity event planner allows the user to plan events and invite other users in their community.	Users can invite/ be invited to engage in physical activities with friends.

TABLE 10: SUMMARY OF DESIGN CONCEPTS FOR HEALTHSIT (NOTE: WHERE STUDENT GROUPS DID NOT NAME THEIR CONCEPTS, A TITLE WAS PROVIDED BY THE AUTHORS)

STUDENT GROUP	DESCRIPTION OF FINAL DESIGN CONCEPT	VALUE
Group 7: Game advancement through physical activity	This concept pays much attention to ease of use in clear visual communication a graphical representation of user data for self-monitoring. It includes an option to get professional advice on behavior and alerts users when they have been sitting too long. To trigger users to follow suggestions to increase movement or change their posture, this concept suggests a collaboration with popular digital game and puzzle applications. When the activity suggestion is followed, users gain some advancement in the game in the game/puzzle application.	With this application users earn achievements in their game application and can consult trusted professionals about questions and to get suggestions.
Group 8: HealthSit as game controller	In this concept, graphical changes are made to make graphical history of collected data clearer. In addition, active sitting is encouraged by using the HealthSit mat as game controller for Wii Fit or to turn pages of an E-reader. Reminders can be set, aimed to trigger interaction and game play.	Clear visuals allow users to gain insight into their sitting habits. Users play games on the TV and sit more actively while reading from their e-reader.
Group 9: Credible System	This concept stresses the need for a clear visual and auditory interface suited to the visually impaired. It allows user options regarding push notification reminders and grades user's sitting behavior daily, on a five-point star scale. This application is intended to help users together with their doctor to keep track of their movement. Adherence to target behavior earns user discount on health insurance.	Users earn discounts on health insurance while receiving more continuous care and attention from their care provider.
Group 16: App for Physiotherapist	This concept includes a controller module for older adults without smartphones to use the HealthSit app. Collected data is shared visually with a physiotherapist via an application designed for professionals of this profession to gain more insight into their patients' health conditions. The module for users can communicate alerts and praise.	Users can expect more complete care from more informed physiotherapists.
Group 17: Sharing app	This application supports user self-monitoring through a summary of activity and includes a chat function in which users can chat and share their data with friends. This system hopes that sharing will lead to planning social physical activities. This system provides warnings when the user has been sitting too long or sitting in the wrong position.	Users can share and discuss their data with other users. In this chat function, users can also invite/be invited to join activities with friends.
Group 18: Sitting competition	This application redesign allows users to track their behavior and receive grades based on a point scale, receive tips created by experts, see praise or alarm notifications about behavior, and compete with their family and other users. This concept emphasizes user-friendliness, simplifying the setup of sensors due to users' low technology acceptance rate.	Users can enjoy praise and see tips that will help them do better. They can also compete with their friends and family using a performance grading system.

Table 11, reports on the focus group's average agreement score for each statement. We can conclude that concept 10, 12 and 15 are evaluated as best by potential users in the focus group and concepts 17 was evaluated as worst but all concepts rank between 2.9 and 4, with 3 being the average possible score. Thus, all concepts were deemed sufficiently similar in quality to be acceptable to include in our analysis.

TABLE 11: FOCUS GROUP COMPARATIVE CONCEPT EVALUATION SCORE (OUT OF FIVE)

	MI-BAND BY GROUP NUMBERS						*HEALTHSIT BY GROUP NUMBERS*					
	10	**11**	**12**	**13**	**14**	**15**	**7**	**8**	**9**	**16**	**17**	**18**
General Concept Score:	4.0	3.1	4.0	3.5	3.6	4.0	3.6	3.6	3.0	3.5	2.9	3.0
I find this concept appealing:	4.3	3.8	4.5	3.0	3.5	4.8	4.0	3.8	2.5	3.5	3.3	3.0
This concept would encourage me to move more:	4.5	2.5	4.5	3.5	3.5	3.8	3.5	3.3	3.3	3.3	3.3	2.5
I can imagine that this concept could encourage others to move more:	4.3	3.5	4.5	3.5	3.5	4.3	3.8	4.0	3.3	3.5	2.8	3.5
This concept would also interest me on a long-term basis:	3.8	2.5	4.3	3.0	3.3	4.3	3.5	3.3	2.5	3.5	2.3	2.3
This concept could in my opinion also interest others on a long-term basis:	3.8	3.5	4.3	3.3	3.5	4.5	3.3	3.8	3.0	3.5	2.8	3.0
This concept can be personalized:	4.8	2.5	3.8	4.5	4.3	4.0	4.3	3.3	4.3	4.3	3.8	3.5
This concept is realistic in my opinion:	4.3	3.8	3.3	3.8	4.0	4.0	3.8	4.0	3.0	3.8	3.0	3.3
This concept is accessible:	4.0	3.5	4.3	4.0	4.0	4.0	4.0	4.3	3.5	3.8	3.3	3.3
There is something about this concept that has to change to make it work:	2.8	2.5	3.0	2.8	2.5	2.8	2.8	2.5	2.0	2.5	2.0	2.5

Through careful examination of the submitted final reports, concept videos and presentation slides each student group contributed, we identified the persuasive principles in each final concept. Initially, this resulted in an extensive list of all the persuasive principles found in each design concept (Table 12). From this list, it becomes clear that students applied a combination of persuasive principles to adapt activity tracking sensor applications to senior citizens in their final concepts. For example, group 12 combines mostly Primary Task Support and Social Support to create a 'Social Map' where users can see other users in their community and close physical vicinity. Users have the option of reaching out to others to invite them to join activities, which will stimulate a more active lifestyle. In this concept users can also see how their level of activity compares to other users.

Table 12: Persuasive Principles in Design Student Concepts, summarizes the persuasive principles found in each design concept. The breakdown of persuasive principles used, shows that primary task support was the most frequently used persuasive category, followed by dialogue support, with credibility support and social support being utilized less frequently.

TABLE 12: PERSUASIVE PRINCIPLES IN DESIGN STUDENT CONCEPTS

Category	Persuasive principle	*MI-BAND*						*HEALTHSIT*					
		10	**11**	**12**	**13**	**14**	**15**	**7**	**8**	**9**	**16**	**17**	**18**
Primary Task Support	Reduction												
	Tunneling			x			x	x	x			x	x
	Tailoring												
	Personalization	x		x	x	x	x	x	x		x		
	Self-monitoring	x			x	x	x		x	x	x	x	x
	Simulation		x						x				
	Rehearsal												
Credibility Support	Trustworthiness												x
	Expertise	x	x					x		x			x
	Surface credibility												
	Real-world feel	x	x										
	Authority							x		x	x		x
	Third-party endorsements												
	Verifiability												
Dialogue Support	Praise					x				x	x		x
	Rewards	x						x		x			x
	Reminders								x	x			
	Suggestion	x		x	x			x		x			x
	Similarity												
	Liking												
	Social role												
Social Support	Social learning		x										
	Social comparison		x	x		x							x
	Normative influence												
	Social facilitation	x		x			x					x	x
	Cooperation												
	Competition												x
	Recognition												
Additional	Goal setting	x			x								
	Sharing			x									
	Self-logging				x								
	Notification					x							x
	Chat											x	
	Negative reinforcement												x
	Economic benefit			x						x			
	Game							x	x				

From the 12 final concepts, it can be observed that many different persuasive strategies were combined. The authors, thus, went on to map all the persuasive principle combinations that the student projects yielded. Once the exhaustive list of persuasive principle combinations had been made researchers examined the frequency of each combination. Table 13: Frequent Principle Combinations, summarizes only the most frequently occurring principle combinations. The numbers in the table reflect how many groups used the respective combination of persuasive principles.

TABLE 13: FREQUENT PRINCIPLE COMBINATIONS

		PRIMARY TASK SUPPORT			CREDIBILITY SUPPORT		DIALOGUE SUPPORT			SOCIAL SUPPORT
PERSUASIVE PRINCIPLE		Tunneling	Personalization	Self-monitoring	Expertise	Authority	Praise	Rewards	Suggestion	Social comparison
PRIMARY TASK SUPPORT	Personalization	4								
	Self-monitoring	4	5							
CREDITABILITY SUPPORT	Expertise	2	2	3						
	Authority	2	2	3	3					
DIALOGUE SUPPORT	Praise	1	2	4	2	3				
	Rewards	2	2	3	4	3	2			
	Suggestion	3	3	4	4	3	2	4		
ADDITIONAL	Social facilitation	4	3	4	2	1	1	2	2	2

The analysis above suggests that a combination of persuasive principles may be used to add value for older adult users and motivate them to move more. The design concepts were clustered based on similar added value. This clustering revealed certain themes, suggestive of the values that are sought in projects of this nature, reported in Table 14: Concepts clustered on similar values. Some projects proposed more than one added value. In these cases, these concepts were clustered twice. The theme, Social fitness, refers to concepts that aim to add value to the user experience by creating opportunities for social engagement, which lead to more physical activity. The value proposed from Improved Care is clear; the application promises better quality of care, usually through providing medical professionals with more insight and information. The projects categorized under Prize have some kind of reward system in common, which either refers to discounts or advancements in game applications. Personalized goals and self-monitoring contribute to user self-awareness. Design concepts in Self-awareness focus on enabling the user to monitor their progress, gain more understanding about their goals/personal achievements and reflect either individually or socially with other users. There were also two concepts that relied heavily on the fun associated with game play, which could also be suggestive of values older adults appreciate in concepts aimed to motivate them to live a more active lifestyle. The values created by a combination of PSD strategies are discussed more in detail below with examples from the collected concepts.

TABLE 14: CONCEPTS CLUSTERED ON SIMILAR VALUES

VALUE THEMES	GROUP	VALUE	STRATEGIES COMBINED
SOCIAL FITNESS	Group 10: Profiling "My Mi Band and Me"	The user receives suggestions and goals that are highly personalized for them. Personalized goals and suggestions can support user self-awareness. Through the suggestions the user can enjoy social activities with other users.	Personalization, self-monitoring, expertise, real-world feel rewards, suggestions, goal setting, social facilitation
	Group 11: Public Dashboard	Older users can reflect their physical activity and enjoy their achievements together with others in a social setting. Users can also expect improved from more informed care professionals.	Simulation, Expertise, Real-world-feel, Social Learning, Social Comparison
	Group 12: Social Map	Users can find friends to join activities. They may also receive discounts from local cafes and museums.	Tunneling, personalization, suggestion, social comparison, social facilitation, sharing
	Group 15: Physical Activity Planner	Users can invite/ be invited to engage in physical activities with friends.	Tunneling, Personalization, self-monitoring, Social facilitation
	Group 17: Sharing App	Users can share and discuss their data with other users. In this chat function, users can also invite/be invited to join activities with friends.	Tunneling, Self-monitoring, Social facilitation, chat
	Group 18: Sitting Competition	Users can enjoy praise and see tips that will help them do better. They can also compete with their friends and family using a performance grading system.	Tunneling, Self-monitoring, Trustworthiness, expertise, authority praise, rewards, suggestion, social comparison, social facilitation, competition, notification, chat
IMPROVED CARE	Group 11: Public Dashboard	Older users can reflect their physical activity and enjoy their achievements together with others in a social setting. Users can also expect improved from more informed care professionals.	Simulation, Expertise, Real-world-feel, Social Learning, Social Comparison
	Group 7: Game Advancement through physical activity	With this application users earn achievements in their game application and can consult trusted professionals about questions and to get suggestions.	Tunneling, personalization, expertise, authority, rewards, suggestion, game
	Group 9: Credible System	Users earn discounts on health insurance while receiving more continuous care and attention from their care provider.	Self-monitoring, expertise, authority, praise, rewards, reminders, suggestion, economic benefit

TABLE 14: CONCEPTS CLUSTERED ON SIMILAR VALUES CONTINUED

PRIZE	Group 9: Credible System	Users earn discounts on health insurance while receiving more continuous care and attention from their care provider.	Self-monitoring, expertise, authority, praise, rewards, reminders, suggestion, economic benefit
	Group 12: Social Map	Users can find friends to join activities. They may also receive discounts from local cafes and museums.	Tunneling, personalization, suggestion, social comparison, social facilitation, sharing, economic benefit
	Group 7: Game Advancement through physical activity	With this application users earn achievements in their game application and can consult trusted professionals about questions and to get suggestions.	Tunneling, personalization, expertise, authority, rewards, suggestion, game
SELF-AWARENESS	Group 10: Profiling "My Mi Band and Me"	The user receives suggestions and goals that are highly personalized for them. Personalized goals and suggestions can support user self-awareness. Through the suggestions the user can enjoy social activities with other users.	Personalization, self-monitoring, expertise real-world feel, rewards suggestions, goal setting, social facilitation
	Group 13: User friendly goal setting	Users receive more attainable, suitable goals. Users can also look back and track their progress gaining more insight into the history and progress of their physical activity.	Self-monitoring, Suggestion, goal setting, self-logging, personalization
	Group 8: HealthSit as game controller	Clear visuals allow users to gain insight into their sitting habits. Users play games on the TV and sit more actively while reading from their e-reader.	Tunneling, personalization, self-monitoring, simulation, reminders
	Group 17: Sharing App	Users can share and discuss their data with other users. In this chat function, users can also invite/be invited to join activities with friends.	Tunneling, Self-monitoring, Social facilitation, chat
FUN	Group 7: Game advancement through physical activity	With this application users earn achievements in their game application and can consult trusted professionals about questions and to get suggestions.	Tunneling, personalization, expertise, authority, rewards, suggestion, game
	Group 8: HealthSit as game controller	Clear visuals allow users to gain insight into their sitting habits. Users play games on the TV and sit more actively while reading from their e-reader.	Tunneling, personalization, self-monitoring, simulation, reminders

We identified which persuasive principles were used most frequently in each value theme. The three most common persuasive principles used throughout each value theme suggested are listed in Table 15: Value themes and combined persuasive principle strategies in order to translate these value clusters into behavior change strategies for actionable implementation.

TABLE 15: VALUE THEMES AND COMBINED PERSUASIVE PRINCIPLE STRATEGIES

VALUE CLUSTERS: PROPOSED STRATEGIES	*COMBINED PERSUASIVE CATEGORIES*	*COMBINED STRATEGIES*
SOCIAL FITNESS	Primary task support and social support	Social-facilitation, selfmonitoring, tunneling, personalization, suggestions
IMPROVED CARE	Primary task support and credibility support	Expertise, suggestions, reward, authority
PRIZE	Primary task support and dialogue support	Tunneling, personalization, suggestion
SELF-AWARENESS	Primary task support and dialogues support	Self-monitoring, personalization, expertise, real-world feel, suggestions, goal setting, social facilitation
FUN	Primary task support and dialogues support	Tunneling, personalization

The value themes listed in Table 15 are from both extrinsic and intrinsic point of view. Social fitness, Improved care and Prize are related to extrinsic motivation while Self- awareness and Fun are related to intrinsic motivation. This consolidated view of the most frequently recurring persuasive principle combinations suggests that certain combinations merit further investigation. For example, personalization and suggestion were found as most frequently used principles for both intrinsic and extrinsic motivation. These observations suggest there is a need for further research to evaluate these recurring persuasive principle combinations as design strategies to motivate older adults to adopt a more physically active lifestyle.

Discussion

In this multiple case study, we explored which motivational strategies might be promising for older adults. A general relative concept evaluation by users was used here because in this investigation, we seek to identify directions for future testing and thus it was only relevant to see that all concepts were of generally equal quality. In future investigations, we suggest further formal user evaluations of the applied design strategies. The suggested design strategies and value themes require further investigation. Due to the limited number of student projects it remains difficult to confidently draw design strategies from these identified themes. It also remains unclear how many of the principles should be combined to gain the designed result. However, we suggest that a combination of several principles can

enrich the system while isolating combinations of only two principles in further testing might allow the researcher to find more direct links between value creation and persuasive principle application. We suggest further research should test the above-identified design strategies, by applying them to a concept design for older users intended to motivate them to engage in more physical activities, before drawing any formal conclusions. Overall, student groups' use of persuasive principles does relate to findings in literature, which often advocates for the use of social devices and personalization to motivate older users (LeRouge et al. 2011) and resonated with the focus group.

Although the obtained results helped us to focus on the potentially relevant persuasive strategies, they failed to help us address the varying needs among the targeted older demographic. To further investigate how persuasive design strategies can be applied to motivate older adults to engage in increased physical activity, profiling could be used to inform which strategies should be applied most effectively. In order to profile users, we suggest combining separate elements from a variety of behavior change theories and model such as the Regulatory Focus Theory (Brockner and Higgins 2001), the Transtheoretical Model of Behavior Change (Prochaska and Velicer 1997) and other personal information such as past experience with physical activities, referred to in chapter two. In this way we create motivational user profiles which could inform the behavior change strategy most appropriate.

Next steps include investigating which personal factors should be included in this motivational profile. Then we can move on to evaluating the strategies we identified as promising here by implementing them in behavior change solutions and testing them in the natural context of living of the specified target audience.

Conclusion

This chapter describes a multiple-case study conducted to explore whether behavior change strategies based on Oinas-Kukkonen and Harjumaa's Persuasive Systems Design (Oinas-kukkonen and Harjumaa 2009) persuasive principles could be used to motivate more physical activities among older users. Twelve student groups used these principles to redesign two existing activity-tracking applications intended for adults who actively engage in physical activity. From analyzing students' work, we have found promising value suggestions relevant to senior users, which need to be investigated further. The two most common values the student design teams used to motivate their older adult users were 'social fitness', aimed at motivating increased activity through social motivations, and 'self-awareness', aimed at providing the user increased insight into their behavior in terms of physical activity. From the collected data, it was clear that all student design groups utilized a combination of persuasive strategies to add value for this specific user group. The further grouping of how persuasive principles were used to create above mentioned value resulted from suggested design strategies also requires investigation. The insights about behavior change strategies gained here will inform design decisions in the next phase of our process, see Part Two: Design of this thesis. In this way we will continue to investigate developing methods to personalize the identified design strategies to better address a diverse older user group.

Datum: 6/04/2017 Tijd: 10 uur

1) Wat zijn de belangrijkste activiteiten die u vandaag heeft gedaan? Gebruik 1, 2 of 3 om aan te geven welk dag deel.

'S Ochtends	Overdag	'S Avonds
1	2	3

☐ boodschappen	☐ commissiewerk	☐ wandelen
☐ op bezoek geweest	☐ hond uitlaten	☐ fietsen
☐ bezoek ontvangen	☐ schoonmaken	☐ koken
☐ winkelen	☐ oppassen	☐ handwerk
☐ computer/ ipad	☐ vrijwilligers werk	☐ TV kijken
☐ fitness/beweging:	☐ anders, namelijk:	

gisteravond maar ik ben op bezoek geweest in de "school" van het K.V.G

3) Wat voor soort maaltijd heeft u gegeten vandaag? (meerdere aankruisen mag)

☒ Zelf gekookt	☐ Maaltijd besteld service
☐ Kant-en-klaar maaltijd	☐ Eten afgehaald
☐ Samen gekookt (bvb met hulp)	☐ Supermarkt
☐ Samen gegeten (bvb ZuidZorg)	☐ Nieuw recept

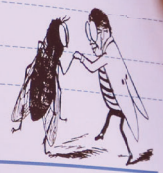
4) Hoe druk vond u vandaag?

1	2	3	4	5
helemaal niet druk				heel erg druk

Datum: / / Tijd: :

7) Wilt u nog iets bijzonders delen over vandaag?

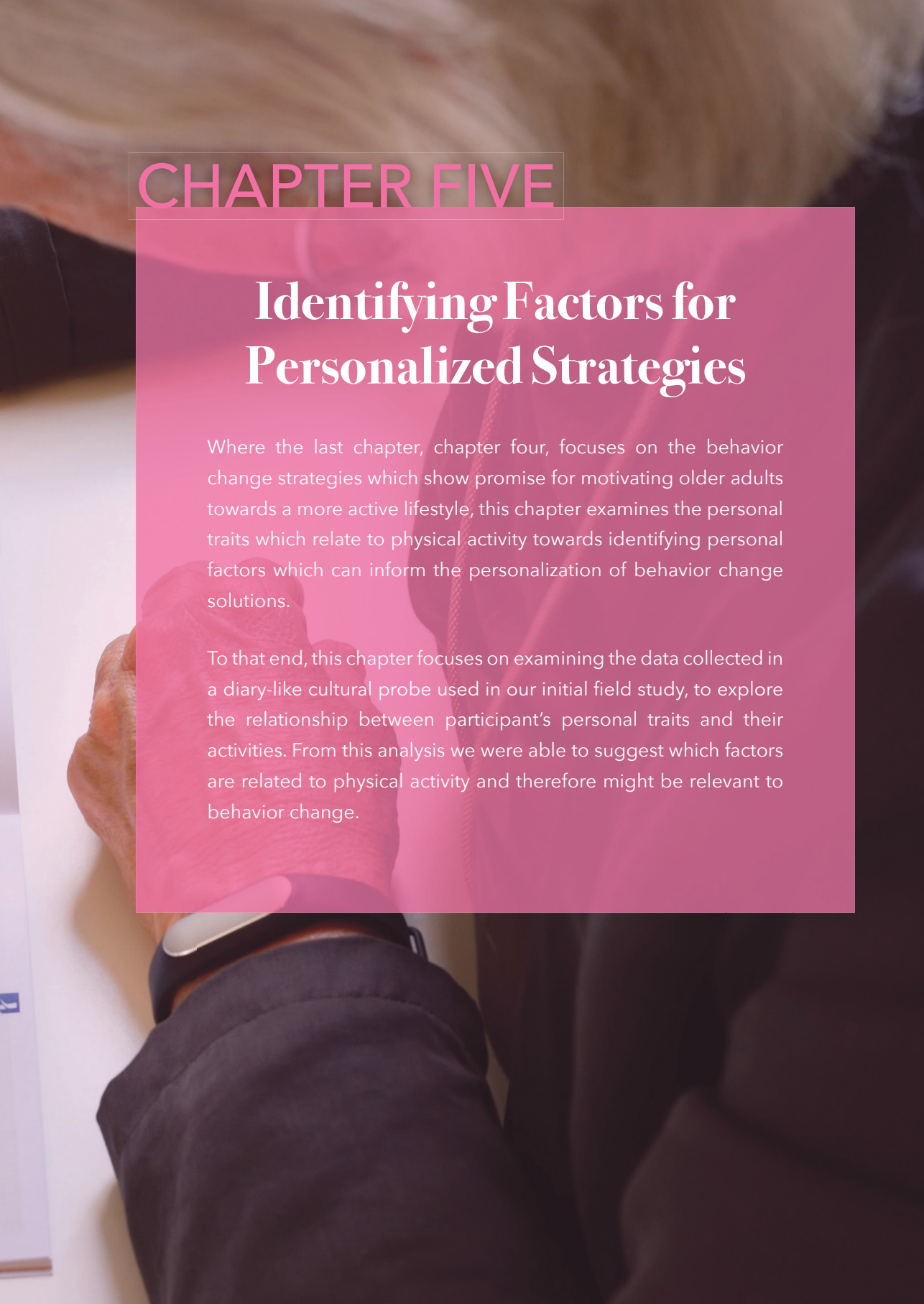
Ik ben lid van het K.V.G = Katholieke Vrouwen Gilde
Het is een heel gezellige Vereniging



De onderstaande woorden vormen een kloppende Nederlandse zin:

Als achter vliegen vliegen vliegen, vliegen vliegen vliegen achterna.

RESPONSIVE ENGAGEMENT OF THE ELDERLY PROMOTING ACTIVITY AND CUSTOMIZED HEALTHCARE



CHAPTER FIVE

Identifying Factors for Personalized Strategies

Where the last chapter, chapter four, focuses on the behavior change strategies which show promise for motivating older adults towards a more active lifestyle, this chapter examines the personal traits which relate to physical activity towards identifying personal factors which can inform the personalization of behavior change solutions.

To that end, this chapter focuses on examining the data collected in a diary-like cultural probe used in our initial field study, to explore the relationship between participant's personal traits and their activities. From this analysis we were able to suggest which factors are related to physical activity and therefore might be relevant to behavior change.

This chapter is based off of work presented in

Valk, C. A. L., Wintermans, M. C., Lu, Y., Bekker, M. M., & Brankaert, R. G. A. (2018). Identifying factors for personalized strategies to motivate seniors to adopt a more active lifestyle. Gerontechnology, 17, 63s. https://doi.org/10.4017/gt.2018.17.s.063.00

And in

REACH Horizon 2020 Deliverable D7.1: Identification and detailing of personalization strategies and degrees of personalization for all Subsystems 6 (associated with task T 7.1)

Introduction

The need to implement behavior change strategies to stimulate older adults to adopt a more active lifestyle is clear. Earlier related work clearly shows the value of personal profiling according to personal drivers toward behavioral intention (Kaptein, Markopoulos, et al. 2015; LeRouge et al. 2011). Though profiling is accepted as a valuable tool in personalizing behavior change solutions (Friederichs et al. 2015; Hardcastle and Hagger 2016; Kaptein, Markopoulos, et al. 2015; LeRouge et al. 2011; Looman et al. 2018), there is little consensus on which user characteristics or personal factors should be used to create such a profile in order to adequately inform design decisions of behavior change solutions. Personal factors such as age and gender are possibly among the most widely used characteristics, yet these factors alone do not give us sufficient insight into the user from which to create useful profiles. Past and current patterns of behavior have been seen to influence behavior (Bandura 1999). If an individual is, for instance already in the habit of going on a walk everyday then to walk a little further is less of an effort than if they are not in the habit of undertaking to walk at all. Possibly predicting a higher chance of adhering to the target behavior, which in this example would be more walking. Beyond these demographics, psychological factors relate to motivation towards behavior changes and are important in understanding and predicting what drives an individual's behavior (Consolvo et al. 2009). For example, the Regulatory Focus Theory, seeks to define the underlying need an individual is aiming to fulfill whether promotion or prevention focused (Brockner and Higgins 2001). It seems likely that depending on this underlying need an individual could respond differently to a behavior change stimulus and thus require a different behavior change strategy. Likewise, an individual's state of health could also influence their physical activities. It is therefore necessary to investigate which profiling factors are important to create personalized motivational strategies for promotion of physical activities.

In this early test, we explore how personal traits relate to behavior in terms of level of physical activity. Personal factors which have a strong relation to physical activities can serve as a starting point to find personal factors which should inform behavior change strategy choices. Here we conducted a study to examine the relationship between personal factors and physical activity among older adults. To this end we use a combination of factors from accepted behavior change literature as the starting point for our investigation.

Method

The aim of this investigation was to better understand which personal traits relate to physical activity as a starting point in identifying which personal factors could influence behavior change towards increased physical activity among older adults. In this observational study both cultural and technological probes were used to explore a variety of personal factors. During the onboarding, participants were given a questionnaire to collect some basic demographic information. Throughout the three-month testing period, community dwelling older adult members of a senior community center were asked to track their daily physical activity by self-reporting their physical activity in a cultural probe and by wearing a provided activity tracker.

Personal Factors Explored

At the beginning of the three-month testing period personal trait information including age, gender, participant perceived age ("what age do you feel?"), perceived health ("how healthy do you feel?" on a five-point scale), was collected. In addition, participants were asked to fill in the stage of change questionnaire (Prochaska and Velicer 1997) and the regulatory focus questionnaire (Brockner and Higgins 2001). Here we used participants regulatory focus and stage of change as the psychological factors because each is so closely related to motivation. As these two questionnaires were not validated in the prevailing local language of the participants, we translated them for the convenience of the older adult study participants. The four questions of the stage of change questionnaire were translated by a fully bilingual member of our research team and the descriptions of physical activity slightly reworded to be more appropriate for the specific group of research participants. To translate the regulatory focus; questionnaire, we needed to undertake a slightly more involved process. First a fully bilingual member of the research team translated the questionnaire into the participants local native language and then we asked a linguist, also native in both English and the local language, to translate the resulting translated version of the questionnaire back into English like the original regulatory focus questionnaire. We compared the original questionnaire to the version which was translated back into English and saw that they were indeed very similar. From this process we presumed that our translated version was satisfactory to use in this study, as we did not have time to go through a more extensive translation process.

Cultural Probe

Participants self-reported their daily activities and reflections in a diary-like cultural probe which combined open and closed questions. In addition, the diaries asked participants to reflect on their emotional state and how busy they felt in order to better understand participant's attitude. Finally an open-ended question was asked to inform the participants' attitude and provides room for them to explain their activities and motivations thereof further. Figure 14 shows an image of one spread of the cultural probe provided to the participants of the study. Researchers asked participants to fill in one spread at the end of each day of the three-month study. The probe was designed to allow participants to share a rich amount of data in a relatively easy way. As such the left side of the spread is formulated like a quick questionnaire design to be filled in quickly and with ease.

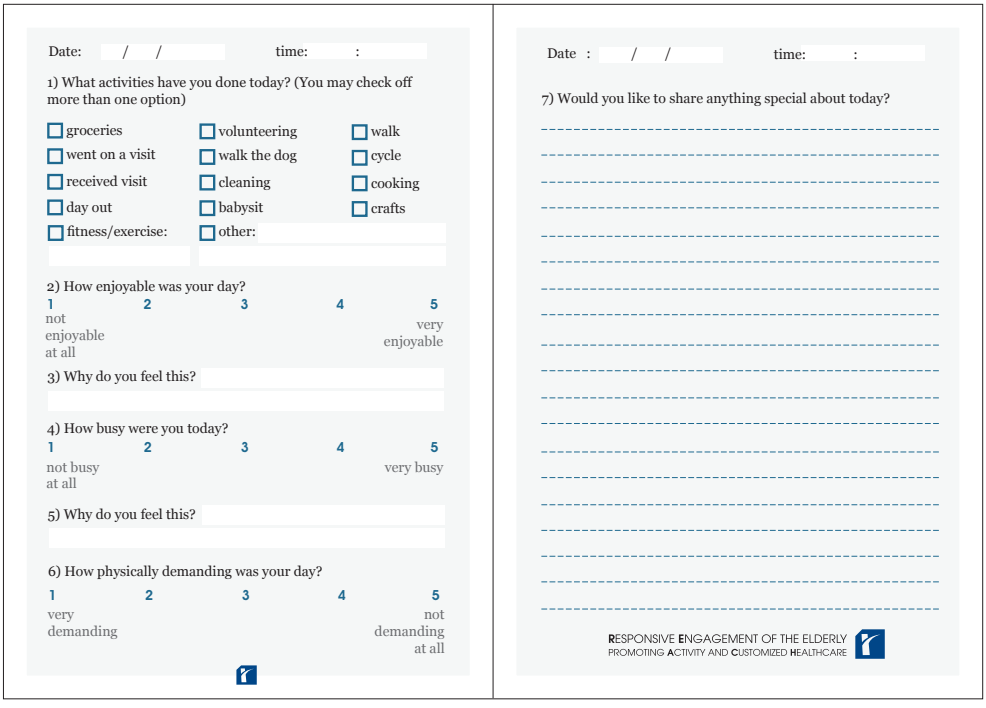


Figure 14: The first version of the diary like cultural probe used in this study

These cultural probes were printed and bound into A5 sized booklets and distributed to older adult participants recruited from the local senior community center at biweekly meetings. Also, at these meetings the completed probes would be collected from the participants. Then the research team would type up the daily entries recoding only the participant's participation number. We conducted a thematic analysis on the qualitative data collected by the cultural probe and the personal trait information questionnaire in order to better understand the relationship between personal traits and physical activity.

Technology Probe

To measure participant's physical activity during this investigation we used the Xiaomi Band (Mi Band), a wearable activity tracker to record participant activity in terms of steps per day. In order to overcome any limitations related to limited technology acceptance on the part of the participants, researchers organized biweekly workshops at the senior community center. During these workshops' researchers collected the data from the technological probe and were able to gain a richer contextual understanding of the information gathered in the diary like cultural probes. For data registration the senior community center provided us with a number of smartphones. The number of available phones was however not enough to assign every participant with a phone for all the participants. Thus, we used a mobile application, AppClone (2016), to connect more than one Mi Band to each phone. By comparing the measured activity data and the self-reported activities to the collected personal trait information we aimed to get a better understanding of how these personal traits relate to physical activity.

Results

All participants were recruited through a local senior community center we partnered with for this research study. Members of the senior community center all lived in independent residences, not in a care home facility, and all of the members of the senior community center have a Tilburg Frail Index greater than 5 (Gobbens et al. 2010), which indicates they only require some care to support independent living such as either a walking aid or some assistants with strenuous household tasks. Of the 52 older adults initially recruited, 44 submitted filled-in cultural probes. In

total 13 participants did not complete the workshop sessions due to health reasons, not wanting to continue or due to unspecified reasons. The use of the pairing App, AppClone, and the unexpected absence of the participants at the planned workshops caused some step data loss in the test. In addition, unknown bugs in the self-made App caused other data lost with the intervention group. Eventually, only step data from 15 participants was collected properly during the test period. The results of this study were two-fold. Initially we gathered some process insights related to needing to redesign the cultural probe and how we coded the qualitative data for the thematic analysis. Secondly, we report on the results from the qualitative data analysis done on the information collected from the personal trait questionnaires and from the daily cultural probe.

Process results

Before we dive into the results of the thematic analysis of the cultural probe, we will first report on the process results relating to both the development of the diary like cultural probe and the coding of the thematic analysis.

Development of the Cultural Probe

Though many participants reported the diary -like cultural probe to be easy to fill in at the biweekly meetings where the research team collected the completed probes and provided new probes, participants mentioned that they found the diary probes boring to fill in. In addition, as we were processing the data throughout the process, we found that many participants were filling in the same or similar activities in the "other" option of the activities list question.

To address the requests of the participants, we created a new diary. In this second version of the diary we updated the list of activities to include those activities which were most often written in, including shopping, computer or iPad related activities, fraternity work (which was often seen as distinct from volunteering), and watching television. Furthermore, instead of asking the participants to fill in the same questions every day, the probe evolved to only repeat questions every other day, alternating the spreads in Figures 15 and 16. These figures show that the probe now also provided the possibility to indicate during which part of the day an activity was done and to provide some information about what kind of meal participants ate. This information was collected for a different study about food and physical activity so will not be

reported on in depth here, but it was included in our probe in order to minimize the workload on participating older adults. Last but not least we included a riddle or joke on every page of the booklet we provided to our participants in an attempt to make filling in the diary less tedious. Over, all these changes were well received and during the biweekly meetings participants often shared their favorite riddle or joke from the new and improved diary. Finally, each diary was outfitted with an introduction page explaining the study, how to contact the research team and an example spread as seen in Figure 17.

Figure 15: Alternating spread one of the second version of diary like cultural probe

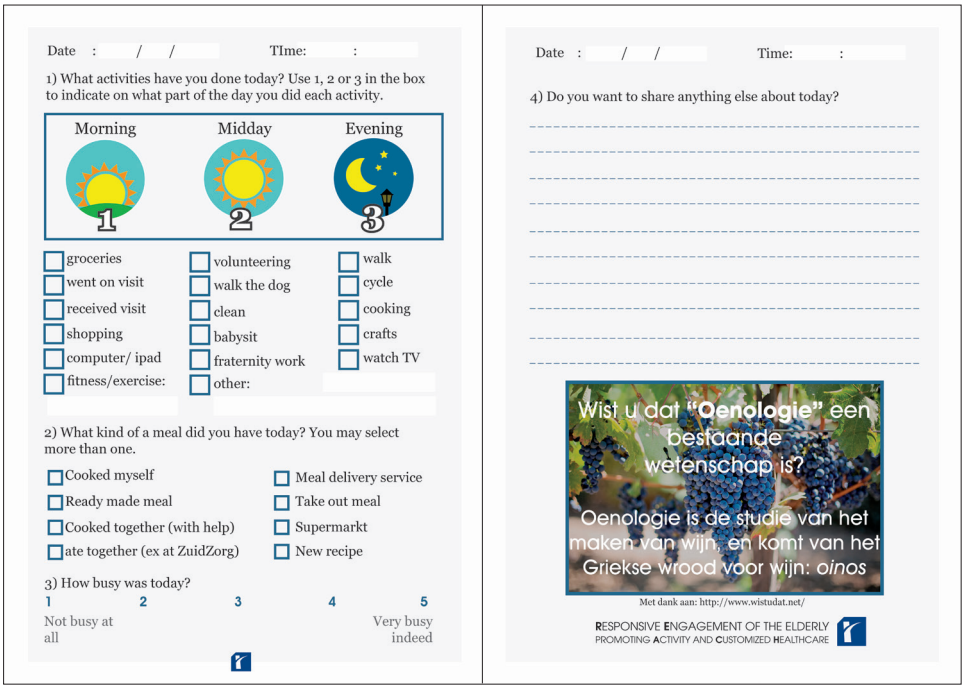


Figure 16: Alternating spread two of the second version of diary like cultural probe

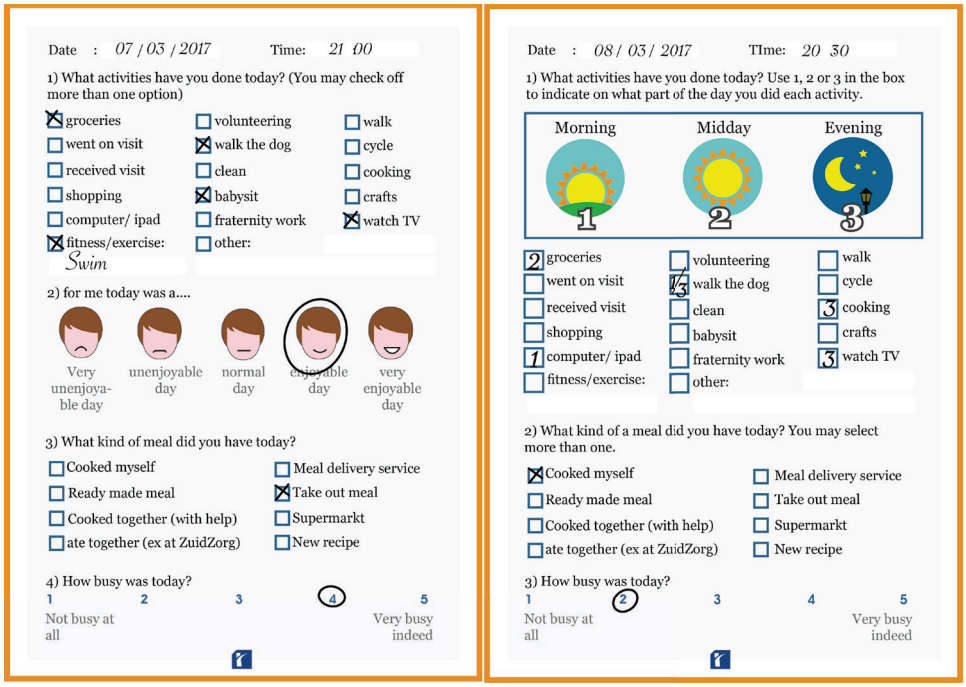


Figure 17: Example page from the introduction section of the cultural probe

Coding of the Thematic Analysis

In parallel to the ongoing research, our research team typed up the diary entries of the participants as they came in. At the end of the study we uploaded the typed up cultural probe data to the NVivo application (a computer program that facilitates the coding and processing of qualitative data) in the form of spread sheets per participant, together with their personal trait information collected from the questionnaires. For this analysis we were interested in the level of physical activity participants were engaging in, what may have motivated these activities and if there were certain personal traits which were often related to either a level of physical activity or a motivational structure. To code the collected information, we defined certain words and phrases into categories such as level of physical activity as shown in Table 16.

TABLE 16: CODES OF THE THEMATIC ANALYSIS

BEHAVIOR			*MOTIVATION EXTRINSIC*		*MOTIVATION INTRINSIC*	
HIGH INTENSITY	*MODERATE INTENSITY*	*LOW INTENSITY*	*STRUCTURED ACTIVITY*	*UNSTRUCTURED ACTIVITY*	*DEPENDENT ON OTHERS*	*INDEPENDENT LIVING*
home trainer	walking	tv	group	man	Helped me	ironing
fitness	taking a walk	read	club	Neighbor	I need help	Folding laundry
gym	golf	administration	volunteering	Friend(s)	Helping me	administration
tennis	shopping	sitting		alone		meeting
cycling	cleaning	cooked		family		Baby sitting
biking						Baby sat
						worked

A word search of all the collected diaries was conducted in NVivo. Words such as home trainer, fitness, gym etc. Were tagged as 'high intensity physical activity' and words like walk, walking, walked, clean etc. Were tagged as 'moderate intensity physical activity'. In this way, the collected qualitative data was sorted into several categories; behavior high intensity physical activity, behavior moderate physical activity, behavior low intensity physical activity, motivation extrinsic structured activity, motivation extrinsic involvement, motivation intrinsic dependent on others, and motivation intrinsic independent living.

Results of the Thematic Analysis

To explore the relationship between participant's personal traits and activities, a word search on the qualitative data from the diaries was done to find how often participants mentioned high, moderate and low intensity physical activities in their daily reported activities in relationship to each of the personal traits we were interested in exploring; gender, perceived health, regulatory focus, and context.

Gender

The number of references which male and female participants made about high, moderate, and low physical activities (see details in Table 17) was compared using a non-parametric test correlation analysis using Spearman's rho correlation efficient. Since the data does not suggest normality, we applied non-parametric test correlation analysis using Spearman's rho correlation efficient based on bootstrap. With 95% confidence, this analysis implied that female participants reported undertaking a higher diversity of physical activity in terms of intensity compared to male participants (Spearman's rho=0.878).

TABLE 17: NUMBER OF REFERENCES TO PHYSICAL ACTIVITIES WITH DIFFERENT LEVEL OF INTENSITIES MADE BY PARTICIPANTS WITH DIFFERENT GENDER

	HIGH LEVEL	*MODERATE LEVEL*	*LOW LEVEL*
MALE	226	232	341
FEMALE	345	771	936

Perceived Health

A similar analysis was conducted to examine the number of times high, moderate and low physical activity was reported in the diaries of participants with different levels of perceived health (see details Table 18). Since the data does not suggest a normality, we applied non-parametric test correlation analysis using Spearman's rho correlation efficient based on bootstrap. This analysis indicated, with 99% confidence (Spearman's rho=0.698), that participants with higher perceived health undertook activities with more diverse levels of physical intensity. The number of references

participants made to physical activities of different levels in their cultural probes, was not found to be significantly related to higher levels of physical activities (Spearman's rho=0.265 with 99% confidence). We also found that more active older adults do not necessarily engage in activities with a higher level of physical intensity.

TABLE 18: NUMBER OF REFERENCES TO PHYSICAL ACTIVITIES WITH DIFFERENT LEVEL OF INTENSITIES MADE BY PARTICIPANTS WITH DIFFERENT PERCEIVED HEALTH

	HIGH LEVEL OF INTENSITY	*MODERATE LEVEL OF INTENSITY*	*LOW LEVEL OF INTENSITY*
Perceived Health = Not Healthy at all	4	20	10
Perceived Health = Not Healthy	5	35	14
Perceived Health = Reasonably Healthy	257	488	463
Perceived Health = Healthy	175	341	311
Perceived Health = Very Healthy	211	477	309

Regulatory Focus

In this investigation we were interested to see if participant's regulatory focus (whether prevention or promotion) related to the amount of physical activities they undertook. Yet in a linear regression analysis, no significant difference was found between the number of steps participants with a promotion regulatory focus or a prevention regulatory focus made. Figure 18 illustrates that there is not a significant difference in the steps taken over time by participants who had a promotion regulatory focus and those who had a prevention regulatory focus.

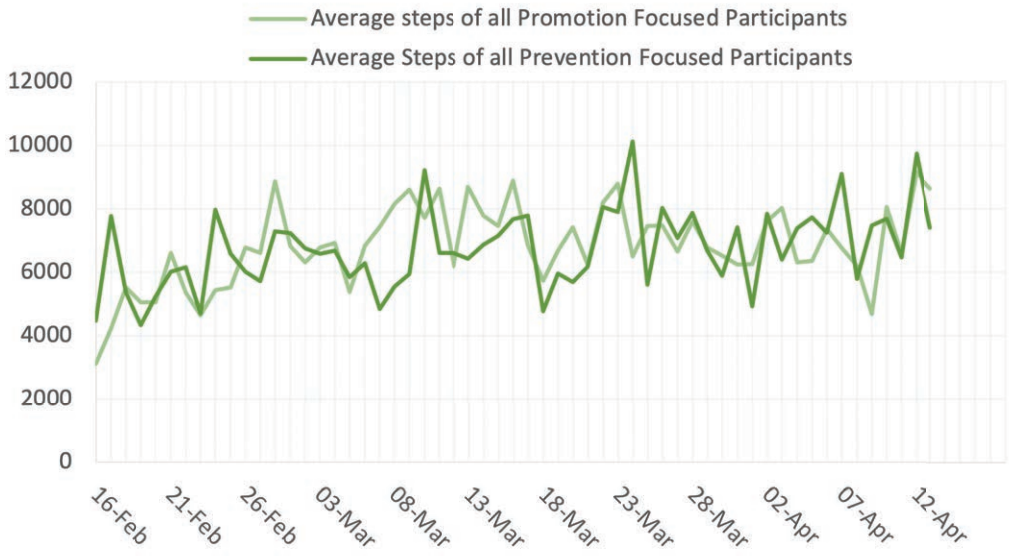


Figure 18: Average steps of all promotion and prevention focused participants measured per day

Context

Participants used both the cultural probe and the wearable step tracking in their natural context of living, in their own independent homes and visited the senior community center on a biweekly basis so that the research team could collect their data. After creating the graph depicting steps over time, Figure 18 in the last section, we were curious to see if there was a relationship between the number of steps taken and the day they were taken; could time of year affect the amount of physical activity?

In fact, the test of the coefficients in the linear model below reveals that there was a significant correlation between the number of steps taken and the moment that they were taken, Table 19: Coefficient analysis.

TABLE 19: COEFFICIENT ANALYSIS

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	5487.606	481.189		11.404	.000
	month	705.846	164.454	.377	4.292	.000
	RFT	-78.193	222.138	-.031	-.352	.726

In order to learn whether there is a difference in the number of steps taken by older adults with different regulatory focuses (promotion focus vs prevention focus) and at different moments (Feb, March and April) in the test period, we conducted a linear regression analysis. The resulting ANOVA table, Table 20, suggests that the linear relation does exist.

TABLE 20: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26081630.292	2	13040815.146	9.273	.000b
	Residual	156103480.699	111	1406337.664		
	Total	182185110.991	113			

Discussion

In this section, we will first discuss the process related results from this study and then discuss each of the personal traits found to be relevant to physical activity in our thematic analysis.

Discussion of Process Results

During this study we found it best to adjust and redesign the cultural probe we used based on the feedback from our participants. It is important to engage our participants in the activities we request of them. To do this it was helpful to process the probes as they were being returned to us on a biweekly basis because this allowed us to make improvements along the way. It also allowed us to undertake relatively quick action on the requests and suggestions of our participants which seemed to be appreciated by many. Participants were able to see tangible evidence of their feedback was being used the very next time we saw them in the biweekly workshops. Though developing this cultural probe was not the main objective of this study, iterating on this probe using the participant's suggestions might have helped the participants feel the importance of their involvement even though the results of the qualitative analysis would take much longer to process. We reflect that often participants only see the results of their input quite a long time after the study they participated in has finished due to the time necessary to analyze collected data and process these findings in a shareable format. This could be anticlimactic to some. So even though the development of the cultural probe was not central to our research objectives we gained a valuable take away from reflecting on the impact of the redesign of our cultural probe.

Our other process related result concerned the coding of the diary entries. During the three months of this study we collected a huge amount of qualitative information, so it was desirable to speed up coding in some way. Thus, we collected typical words and phrases from a subsection of the diaries and used these in a word search to quickly code a large amount of collected data. Though this word search allowed us to quickly code a large amount of data; the limitation of this word search is that possibly some text indicating a particular activity might not be counted because participant word choice differed from the word search, even though we tried to search all tenses.

In this study we experienced several issues related to the quantitative data collection. In the first place due to bugs in our own created software. We learned the hard way how important it is to make sure to have an absolutely robust data collection software in place before starting the test as it was difficult to trouble shoot at a distance in between the biweekly meetings. Furthermore, it would have been useful to anticipate tech-related issues and facilitate a way to address these issues as they come up. Finally, even though the participants were only asked to wear the step tracker we still received several questions on how and when to wear the tracker so providing the participants with an easy way to answer frequently asked questions and solve anticipated problems could be really beneficial for future research.

Discussion of Thematic Analysis Results

In this section we will examine each of the personal traits we investigated more closely to find traits which could be used for profiling towards personalizing persuasive strategies for Behavior change solutions.

Gender

In this study we saw that female participants reported a higher diversity of activities in terms of the activity's level of intensity. If gender is related to the kinds of physical activity older adults undertook without any intervention, this personal trait might also inform the kinds of physical activity stimulating input or feedback older adult users might respond to. Further research is needed to see if gender is a profiling factor which could inform behavior change strategy choices in the development of physical activity promoting interventions and behavior change solutions.

Perceived Health

As one might expect, participants with a higher perceived health also engaged in more physical activity. Yet further research is needed to see if participant's actual state of health or if their belief in their personal ability to succeed at an activity might cause this correlation. Naturally, physical activity promoting solutions should take the users personal mobility and physical capabilities into account. Yet in addition it could be very beneficial to take the user's belief in their ability to succeed at an activity, or self-

efficacy, into account as well. Further research is needed to see to what extent the user's self-efficacy should be considered a meaningful factor to personalize behavior change solutions.

We did not necessarily see an indication that older adults who were more physically active performed activities of at a higher level of intensity; they usually just undertook more moderate intensity activities. This could be explained by the general level of physical physique of this group of older adults: all of the members of the senior community center have a Tilburg Frailty Index greater than 5 (Gobbens et al. 2010). Again, this points to the importance of self-efficacy as a relevant factor for personalizing behavior change solutions aiming to promote physical activity, because it shows that older adults with some physical limitations can still increase their physical activities even if they do not increase the level of intensity of these activities.

Regulatory Focus

In this investigation we were interested to see to what extent psychological traits, such as regulatory focus, related to physical activities undertaken by older adults. It was found that there was no significant influence of the regulatory focus results on the number of steps taken by the participants. This result could be attributed to several causes; potentially regulatory focus just does not affect the kinds or amount of physical activity older adults undertake. Another cause could be that the questionnaire did not correctly measure this construct due to our translation of it. While filling in this questionnaire many participants had questions, and some said that the questionnaire was difficult to understand or difficult to answer. The fact that the questionnaire was not specifically designed for this group of users could also be a reason that it might not have actually tested the constructs we were interested in. For these uncertain reasons it seems advisable to move away from using the regulatory focus theory in our next study and utilize a different psychological construct, such as possibly self-efficacy as mentioned above, instead.

Context

Here we found that the number of steps taken was correlated to the time period they were taken in, specifically the month of the year. This reiterates the dynamic nature of behavior and therefore behavior change. This could be due to the gradual

improvement of the local weather from February until April, the time frame of our study. As the weather improves older adults might feel more inclined to go outside for a walk or other physical activities such as gardening. This could suggest that personalized strategies addressing participant's context can also increase motivation to physical activity. Interestingly, a recent doctoral thesis found that environmental context, such as proximity to shops, parks and overall esthetics of the neighborhood, can affect the amount of physical activities older adults engage in (Liu 2020). As we did not investigate proximity to parks and Lui, 2020, did not investigate the effect of weather, further research is needed to understand which contextual elements could effectively be used to personalize strategies to motivate increased physical activity among older adults.

Implications for Personalisation

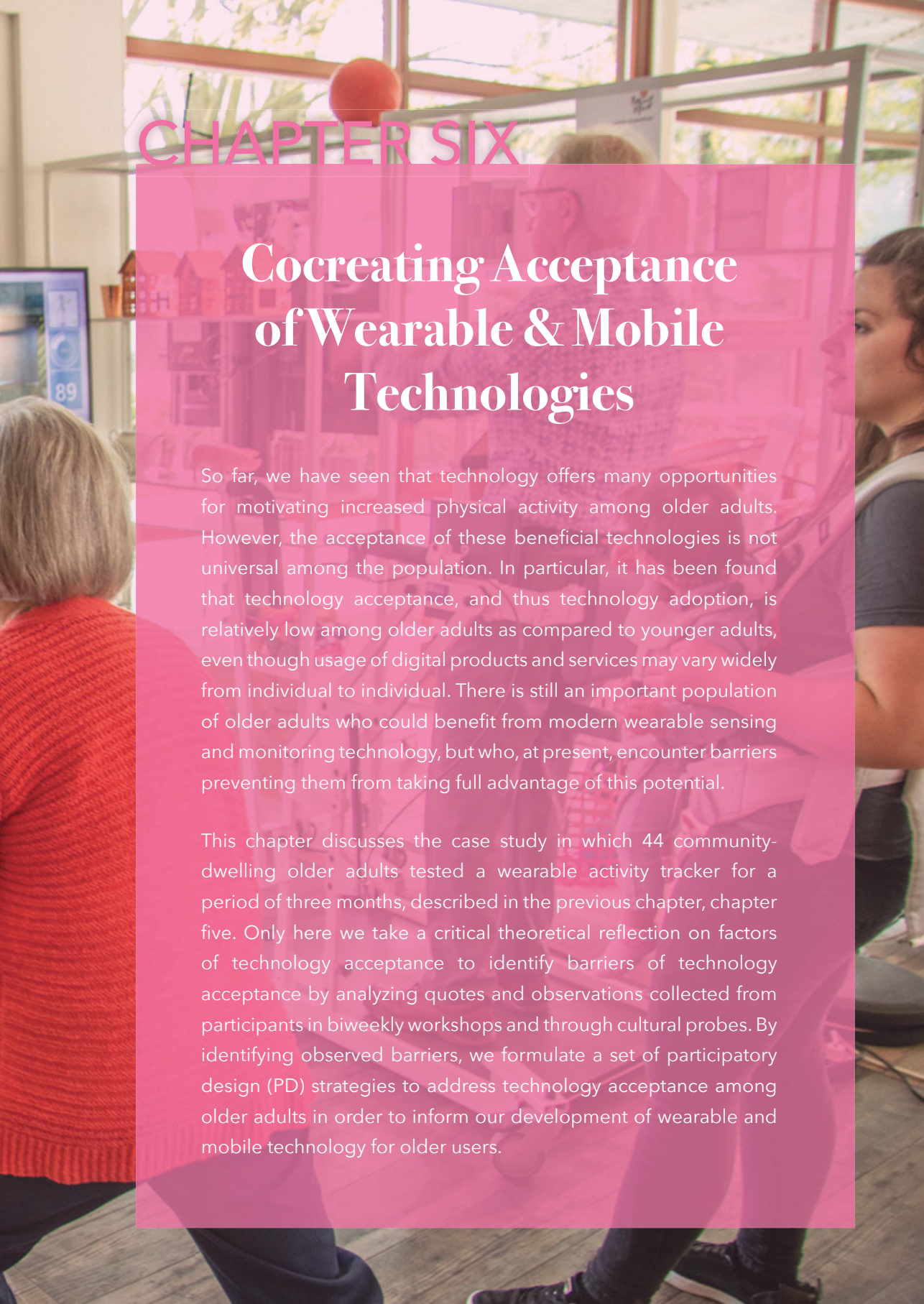
In this investigation our aim was to explore factors related to physical activity among senior community center members. From the discussion above we anticipate factors related to measured behavior, personal or psychological being and the user's context to influence the dynamic process of behavior change. However, the exact factors which should determine appropriate behavior change stimulating input are still not defined. Though in this study we found that participants had little objection to the collection of their measured physical activity data, there might well be a group among the very diverse older adult population who are not comfortable with this data being tracked even for the purpose of motivating healthier lifestyles through increased physical activity. Furthermore, there are other personal factors which will likely need to be collected or measured such as age, gender, relevant psychological factors and contextual information, which can raise questions about user privacy and data security. In this study we collected personal information through a diary like cultural probe, but we have fund that this method of collection is not scalable, thus raising the questions about how this information should be collected or tracked. Though it might be tempting to assume the more data we measure the better, in terms of personalizing behavior change strategies, this approach could result in unnecessary data collection and storing irrelevant user data. Such practices are discouraged by the EU's independent data protection authority, as stated in Article 5(1)(c) of the GDPR and Article 4(1)(c) of Regulation (EU) 2018/1725, which provide that personal data must be "adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed" (The EU's independent data protection authority 2018). As we continue our investigation into how personal factors can inform applied behavior

change strategies, we need to also consider the implications of measurement of this personal information in terms of privacy concerns and load on the users. Therefore, the goal of future work should be to narrowly define which behavioral, personal and contextual data is most likely to inform the effectivity of behavior change strategies, so that future behavior change technologies can be more intentional with the personal data collect.

Conclusion

The results from this study provide input on how to formulate personalized motivational strategies to inform behavior change, by identifying personal factors related to physical activity.

Though our initial goal of this investigation was to gain a better understanding of the personal traits associated with physical activity as a starting point towards personal profiling for behavior change, we also found, we faced certain note-worthy challenges during the execution of this study, mainly related to technology acceptance. Therefore in the next chapter we took a closer look at and reflected on the barriers and facilitators of this study to learn how to approach future in-context studies with older adult members of our local senior community center.



CHAPTER SIX

Cocreating Acceptance of Wearable & Mobile Technologies

So far, we have seen that technology offers many opportunities for motivating increased physical activity among older adults. However, the acceptance of these beneficial technologies is not universal among the population. In particular, it has been found that technology acceptance, and thus technology adoption, is relatively low among older adults as compared to younger adults, even though usage of digital products and services may vary widely from individual to individual. There is still an important population of older adults who could benefit from modern wearable sensing and monitoring technology, but who, at present, encounter barriers preventing them from taking full advantage of this potential.

This chapter discusses the case study in which 44 community-dwelling older adults tested a wearable activity tracker for a period of three months, described in the previous chapter, chapter five. Only here we take a critical theoretical reflection on factors of technology acceptance to identify barriers of technology acceptance by analyzing quotes and observations collected from participants in biweekly workshops and through cultural probes. By identifying observed barriers, we formulate a set of participatory design (PD) strategies to address technology acceptance among older adults in order to inform our development of wearable and mobile technology for older users.

This chapter is based off of work presented in

Valk, C. A. L., Lu, Y., Randriambelonoro, M., & Jessen, J. (2018). Designing for technology acceptance of wearable and mobile technologies for senior citizen users. In Next Wave: the 21st dmi: Academic Design Management Conference Proceedings (pp. 1361-1373). Boston: The Design Management Institute.

Introduction

In recent years, wearable technologies have been developed for a variety of markets. These technologies offer new sensing and monitoring possibilities; allowing users to gain more insight into their health, through continuous measurement. This potential is already being readily enjoyed by runners and other exercise enthusiasts. Similar to providing training insights to exercise enthusiasts, wearable technologies are being used to monitor sedentary behavior and stimulate more physical activity, among office workers (Stephenson et al. 2017). However, these wearable technologies still offer untapped potential for a user group, whom, generally speaking, is not overly accustomed to using such devices. Wearable technology can provide valuable feedback to community dwelling older adults about their health and physical wellbeing, however many older adults experience barriers to the adoption of this new technology.

Current off-the-shelf wearable sensors are generally not designed with the specific needs and barriers of this target audience in mind. Though early models of technology acceptance have been developed further to address the unique needs and challenges some older adults face, there is still a tendency to assume that if the interface meets basic usability requirements (for example related to color contrast button and font size) that an interface or application will be adopted (Renaud and Biljon 2008). Sources indicate that designing technological interventions in such a way to make them acceptable to older adults unused to digital technologies is often not enough to result in the adoption, or regular use, of that intervention (Renaud and Biljon 2008). The reason for this reluctance is that just because an application is usable for older adults does not mean it is relevant to their values and daily lives and routines. To make sensing and monitoring interventions relevant to this audience, designers should empower older end users to collaborate on the design of interventions which support their independence.

Codesign methods, like participatory design (PD), can empower end users to communicate their needs and participate in the development of new behavior change technologies (Davidson and Jensen 2013; Demirbilek 1999; Iversen et al. 2012; Lindsay et al. 2012). The PD process could be particularly important to the development of technological products for older adults who face barriers to technology acceptance and adoption as this collaborative design method allows designers to consider the user's values and needs beyond the limitations they

experience with technology. However, we need to investigate how a PD process can be used to support technology acceptance among older adults because designing meaningful technologies for older users remains a challenge.

In this chapter we examine the challenges and barriers recorded during the three-month investigation described in chapter five, where off-the-shelf wearable tracking technologies were provided to members of a senior community center, for use over the course of a three-month period. From the thematic analysis of this case study, certain factors for technology acceptance are identified. We provide suggestions here as to which PD approach could help to address these identified factors of technology acceptance among older users for use in future product development. This critical theoretical analysis will result in a PD process for older adult technology acceptance, which we used as a starting point for our design process in part 2 of this thesis.

Method

Though some of the set-up of this investigation was described in the last chapter we will quickly reiterate here aspects of our approach which are specifically relevant to the analysis in this chapter. This chapter applies grounded theory to the qualitative findings from an early investigation about amount of physical activity among members of a senior community center described in the last chapter. Data collected for this reflection, was reviewed by researchers from three different universities affiliated with the European Horizon 2020 project REACH. During the qualitative analysis, we reviewed the collected data, coded them gradually and created categories describing factors relevant to technology acceptance for older adults. These categories may become the basis for a new theoretical PD process strategy to support older adult's technology acceptance.

Investigation Setup

Both a cultural probe and a technological probe, as well as a questionnaire in which participants reported demographic and psychological factors (see Table 21), were used to collect the data over the course of a 3-month period, from February to April 2017. The cultural probe used took the form of a diary in which participants answered some open-ended and some multiple-choice questions about their day.

The technological probe used during this investigation was the Xiaomi Mi Band 1 to measure daily step count of the participants. This simple wearable probe was selected based on the ease of use of the product. It is waterproof and has a long battery life (the website sites about two months) thus participants would not have to charge it themselves and would not have to remove it when they took a shower or bath. This was considered an asset because overall technology acceptance with this user group was considerably low.

During this study, researchers met with participants in workshops every other week. For these workshops, the total participant group was split into four workshop groups both for practical (space) reasons and because the senior community center experienced professionals recommended to researchers that participants would prefer meeting in smaller groups. These workshops were meant for extracting information from the Mi Band. About half of the participants used the Mi Band application on a provided phone to extract their data themselves while other participants were provided by their data on paper by the researchers. These groups were randomly distributed by representatives of the senior community center, not the research team. The workshops also served as an opportunity for the researchers to charge the Mi Bands of the participants, and to collect the filled-out diary probes. The workshops also gave researchers and participants time to discuss their experiences with the technological probe.

TABLE 21: OVERVIEW OF INVESTIGATION DETAILS

TECHNOLOGY PROBES	Mi Band
CULTURAL PROBES	Diaries
QUESTIONNAIRES	Translated RFT (Brockner and Higgins 2001) and Stage of Change (Prochaska and Velicer 1997) questionnaires as well as some demographic information
QUALITATIVE DATA COLLECTION	Workshops
DURATION OF STUDY	3 months
NUMBER OF PARTICIPANTS	44 participants
AGE OF PARTICIPANTS	58 - 90 years (average age 76.3)
CONTEXT	Senior community center
PURPOSE	Observe baseline in physical activity among older members of the ZuidZorg senior community center

Thematic Analysis of Results

For this investigation, 44 older participants were recruited at ZuidZorg Extra (ZZE), senior community center in the Southern Netherlands. The inclusion criteria were member of the local senior organization, living at home, and in need of occasional help for their daily activities (e.g., help with cleaning and grocery tasks to mobility support aids or prolonged medication treatment). All participants were between the ages of 58 and 90, and the average age of all participants was 76.3. The participants include 33 females and 11 males. All participants were local to the Netherlands and spoke Dutch. Most participants reported to have limited digital technology ability though several had cell phones, and some reported having and using an iPad. One participant was adept at using the computer and explained it was their hobby. The researchers collected qualitative data to gain insight into the activity of the participants.

This section will report on the findings from the thematic analysis. Findings were clustered under themes; under each recurring theme factors related to technology acceptance or rejection were identified. The discussion provided a reflection on each factor and suggested PD strategy, which might be applied to address factors, which seemed to be barriers, and support factors, which seemed to facilitate technology acceptance in the participants. A grounded theory approach was used to thematically cluster findings, quotes, and observations before discussing and coming to a clustering consensus. The resulting factors pertaining to technology adoption or rejection included technology has potential, social connection as a facilitator for technology acceptance, issues surrounding usability, and apprehensions about technology use.

Technology Has Potential

In this multiple case study, participants showed indications of a positive attitude toward the technological probes that they were asked to interact with throughout the study. These observations are promising for technology acceptance among this user group, but also offer some insight into a direction for designer's future work.

Participants largely started out a little apprehensive about using the technology yet gained confidence in their use and interaction throughout the study. Participants

displayed their conviction of the added benefit of the technology further in the interest they took in their data. Some participants repeatedly asked if they could see or access their data in a more continuous form, clearly expressing their curiosity about their measured data.

Beyond indications that the technological probes could be accepted, used and appreciated for their added potential, the participant's tendency to want to customize their use of the introduced technology was perceived as an important theme. Participants often wanted to share their individual preferences and habits about the technology use. In addition, researchers found that a personal one on one explanation of the applications used was much more effective than step-by-step group instruction.

Social Connection as a Facilitator for Technology Acceptance

In this investigation, social connection was found to be a facilitator. In this study, a feeling of social connectedness manifested itself in three distinct ways; participant to researcher (where participants enjoyed the social aspects of participation in the research study), peer to peer (participants reported being proud to share with their peers) and personalized training (participants seemed to respond to personal training which facilitated their use of the provided technologies). From this examination of the social interaction of the participants, we can discern how social interaction can be an important facilitator in technology acceptance.

Usability Issues

Despite what the potential technology promises to this user group researchers observed that participants experienced many usability issues including discomfort from the wearable technology and difficulties with use and maintenance.

Discomfort

It was observed that many participants experienced discomfort due to symptoms related to aging, such as the swelling of extremities and arthritis, which likely were not considered when these wearable devices were designed. The wearable trackers used in these studies are comparable in design as other competing models on the market (Randriambelonoro et al. 2017), suggesting that many similar products would result in the same discomfort.

Difficulties with Use and Maintenance

Usability issues were not limited to discomfort but also led to other difficulties. Taking the wearables off and putting them back on was a challenge for nearly every participant in this study. Thus, charging this technology was also a challenge, because even without taking the wearable on and off, removing the sensor from the wrist band and plugging it in to charge was seen as difficult by all participants. Finally, this challenge was resolved so that participants did not need to charge the sensor themselves, but research assistants took on this task for them.

Unfortunately, even when the sensors were charged correctly, those participants who used walking aids did not receive realistic data because the wrist-worn sensors did not pick up their steps as they walked with their walker. The accompanying application also posed challenges in that the data charts were hardly legible to participants and the interaction reportedly confusing.

Doubts and Apprehension about Technology

Besides the barriers to usability discussed, researchers observed that doubt and apprehension about the technology formed a barrier for many participants to accept the novelty of new technologies into their highly personal daily routines. All the researchers of this observational study put effort into building report with participants and strove for open and friendly communication. Researches communicated the aim of the study was to learn about how much and what kind of physical activity participants of the study were already doing and thus that no amount of physical activity, or lack thereof, was in any way wrong. Despite the attention to participants comfort and confidence, one participant who opted to discontinue the study and

explained that merely wearing the tracker, constantly made this participant question if they were being active enough or not.

Furthermore, participants expressed uncertainty about the accuracy and the different functionality of the devices, by asking many varied questions about this. Notably, two participants asked if the activity tracker would interfere with their pacemaker. These uncertainties could cause some people to feel apprehensive about the adoption of new technologies.

Discussion

This investigation identified facilitators and barriers to technology acceptance among older adult members of a senior community center. These identified barriers block an important subset of older adults from the potential positive impact of wearable sensing and monitoring technologies. Examining these barriers and facilitators could inform future technology development towards more accessible products for older adults. Despite the general older adult population being highly diverse, there were some traits shared by many members of this group of participants. All participants were local to the Netherlands and preferred Dutch as their main language. In addition, many of the participants had very limited experience with technology and 33 out of 44 participants were female. These similarities in an otherwise very diverse group might limit the extent to which these results represent the greater population, though still representing a subset of older adults who are not so familiar with technology and who might benefit from the potential wearable technology offers.

In the previous section, we identified a number of factors important to technology acceptance for older adults. In this section, these findings are compared to the previous work related to PD, in order to identify PD strategies which can be used to support technology acceptance among older adults. Though the identified factor categories do not constitute an exhaustive list of factors related to technology acceptance, they do relate back to accepted constructs in existing literature. Below, each category will be discussed in more detail to propose how to use PD to address the identified factors of technology acceptance among older adults.

Technology Has Potential

It is important to reflect on the limitations towards positive reactions received from users in any study. Researchers considered that participants could have been positive in an attempt to be agreeable to the researchers or that only those members of the senior community center who already had an innate interest in wearable technology, joined the study. However, both of these explanations seem unlikely; 1) participants were open in sharing both positive and negative feedback and 2) most participants had limited experience with technology.

Participant's positive reaction to the technological probes introduced indicates that technological solutions for aging and health monitoring systems can and likely will be accepted by an older user group when they are introduced under the right circumstances. These observations also give some indications of the important factors that will support technology acceptance by older adults. From this analysis, findings indicate that self-efficacy, user recognition of the added benefits of the system and customization play an important role in supporting the older user group's acceptance of new technologies.

Participant's increase in proactive interaction with the technology provided, suggests that self-efficacy and repeated exposure can play an important role in the technology use. Arguably, since these interactions took place in a workshop setting, these observations might only signify acceptance of technology and not technology adoption. For a new older user to adopt technology into their daily routines and lives, they should recognize the usefulness of the technology (Renaud and Biljon 2008). To facilitate participant's self-efficacy in technology acceptance, designers aiming at creating technological solutions for older users should strive to empower these users to take an active role in the design process (Ladner 2015). It is important here that designers support the user's confidence (Orzeszek et al. 2017) to take an active part in the design process.

In this study promising indications for technology acceptance were observed. A PD process supports usability (Neuhauser et al. 2009) and can offer opportunities to facilitate older user's participation in the design process of the related technologies to support technology acceptance and adoption. In order to support usability for the end users, designers in the design process should work to include the end user in most if not all parts of the design process, beyond only ideation (Iversen et al. 2012).

By including the end users in the design process, designers can create products that embody the needs and values of older adults. As these products are a better fit for their daily lives, older adults will likely be more ready to accept products created using a PD process involving older adults, as compared to the off-the-shelf products used in the case studies reported here.

Social Connection as a Facilitator

Social connection evidently motivated participants to join and to maintain their participation in this study. The important qualities of recruitment seemed to be trust and familiarity. If participating in a research investigation was new to the individual then it was important that they receive an invitation from trusted persons such as members of their activity center, volunteers or well-known employees of the community center. Thus, trusted social contact seemed to be a potential driver in supporting the self-efficacy of participants introduced to new technologies. For this reason, it is suggested that PD processes could support technology acceptance of older adults by including them in a group setting with familiar friends and trusted representatives of the community center. In this group setting, it is important to allow for casual socializing time, not only because social connectedness motivates participants to join the PD process but also because this can stimulate the PD process (Davidson and Jensen 2013).

From this study, it is clear that supporting a feeling of social connection can facilitate users' acceptance of technology into their lives and daily routines. The pride that some participants took when using the wearables seems to indicate that new wearable technologies are potentially attractive to older users. The widespread enthusiasm displayed by participants to engage in the workshops and interviews indicates that they would be likely motivated to participate in a PD process.

Results suggest that there is a need for personalized interaction to facilitate older adults in the PD process. The value of simple dialogue between researcher and participants must not be underestimated here. An open dialog is a good way to learn about end user's needs, values, likes and dislikes (Davidson and Jensen 2013; Demirbilek 1999; Orzeszek et al. 2017). Researchers should put time and effort into building rapport with the participants, and this will facilitate conversation and likely enable the designer to gain a deeper understanding of the end users.

During this investigation participants could rely on the personalized help and training of the researchers to engage with the technological probe provided. This personalized attention and training was important to participants' acceptance of the new technologies provided. Therefore, it is suggested that introduction to the PD process should be tailored to the users in attendance (Orzeszek et al. 2017). What do they expect from this process? How much experience do they have with technology? What do they know about design? These are all important elements to consider when planning the PD process. Researchers here found it was helpful to set up presentations in a flexible way; prepare more examples of different kinds than time will allow. In this way, it can be easier to react to unexpected questions from the participants, and tailor the workshops and activities on the go.

Usability Issues

The wearable technology used in this study was not designed for this target group, as evidenced by the discomforts' participants experienced. A PD process, would have addressed the specific needs of this group, improving the comfort and usability of this wearable tracking technology (Muller, Wildman, and White 1993; Neuhauser et al. 2009). Beyond solving wearable discomfort and maintenance challenges, a PD process could address the usability issues related to the accompanying mobile applications by identifying interaction problems early on in the design process (Demirbilek 1999). The added value of the PD process is solving these usability issues, by helping designers tailor solutions to an older user group and ensuring that the technologies created speak to user's interests.

To enhance the usability of the wearable sensor and monitoring technologies for older adults, PD processes should be used. Cooperative evaluation is a process in which end users evaluate designs and concepts throughout the design process to identify usability issues early on (Muller et al. 1993). This evaluation can be done collaboratively with end users through play acting of future storyboard envisioning (Sanders, Brandt, and Binder 2010). When the concept is more mature, it is also suggested that designers facilitate end user evaluations through user testing and trial tests, in which the prototype will function as near to the end concepts as possible to get the clearest idea of the usability issues which still need to be revisited. Furthermore, it is suggested that, especially with the development

of mobile applications and other information technology which can develop over time, end users can continue to provide designers and developers with feedback and suggestions to continue to improve the design for ongoing development (Dittrich et al. 2002).

Doubts and Apprehension about Technology

To alleviate the doubts and apprehensions about sensing and monitoring technologies observed among participants in this study, researchers suggest the importance of open discourse between participants and researchers. To address these apprehensions, it is imperative that users, design researchers and other stakeholders participating in the design process, are equally and mutually respected (Smith et al. 2017; Spinuzzi 2005).

The role of trusted information from technology suppliers and health professionals might be valuable to soothe concerns some participants expressed about the wearable. Co-creation, during the early stages of the design process of new technologies, can build confidence with new technologies as participants become more acquainted and more comfortable with the technologies in question. The co-creation PD approach might provide the scaffolding needed to support older adults to facilitate their technology acceptance. In light of the positive effect social support has on technology acceptance, mutual learning can provide benefits to older users to continue to practice and learn the techniques and possibilities offered by new technologies.

From this investigation, researchers found that participants regularly forgot how to interact with the systems provided. One possible reason for this is that the off-the-shelf products provided did not adhere to the participants mental model of technology interaction. By including older end users in the design process, design researcher and end users can work together to create a scaffolding which will support not only older adult's understanding of the interaction but also their remembrance of it. In this way, PD can help researchers and designers to propose for example a scaffold approach to introduce complex solutions to apprehensive users in a step by step way and in so doing reduce their apprehension towards technology.

Participatory Design Strategy Toward Technology Acceptance

As discussed above, this analysis of the case study identified a number of practical factors related to technology acceptance for older adults. Participatory design methods and approaches can be applied to address these factors and support technology acceptance for older adults. Here a participatory design (PD) strategy is proposed to be used in the development of future wearable sensing and monitoring technologies for older users. Table 22 summarizes the suggested PD methods and approaches valuable to address technology acceptance among older adults.

TABLE 22: SUMMARY OF THE SUGGESTED PD METHODS AND APPROACHES FOR ADDRESSING TECHNOLOGY ACCEPTANCE AMONG OLDER ADULTS ORGANIZED BY THEMATIC CLUSTER

RECOGNIZED POTENTIAL FOR TECHNOLOGY TO BE ACCEPTED AND ADOPTED BY OLDER PARTICIPANTS		
Technology acceptance factor identified	PD practice/ strategy or approach suggested	Notes/ explanation
Self-efficacy	Self-decision: Empower older adults to take an active design role in the development of new technologies.	Ladner (2015) calls on designers to empower people facing health challenges to take the role of the designer in the design process to ensure usability (Ladner 2015). Orzesek, et al. (2017) argues that older adults should not only be included but should take an active role in designing digital interfaces for older users (Orzeszek et al. 2017).
Perceived benefit	Co-decision: User inclusion in various steps of the design process beyond only ideation	A PD process with older adults and other vulnerable Medicaid users yielded a health communication guidebook in three languages that increased user's confidence and knowledge as well as their intended behaviors (Neuhauser et al. 2009). User participation throughout several stages of the design process will lead to solutions better suited to older adults Demirbilek (Demirbilek 1999).
Customization of technology intervention	Drawing/paper modelling as a way to make low fidelity paper prototypes Design for flexible use	Older adults customized applications to display the information they were interested in (Davidson and Jensen 2013). The codesign process with applications and IT systems is on-going even after the product is developed because users can customize their use of the technology and in this way, will continue to design the use case for it (Dittrich et al. 2002).

TABLE 22: SUMMARY OF THE SUGGESTED PD METHODS AND APPROACHES CONTINUED

INFLUENCE OF SOCIAL CONNECTION		
Technology acceptance factor identified	PD practice/ strategy or approach suggested	Notes/ explanation
Peer to peer social recognition: pride	Group workshop ideation setting	To solidify the design team and have older adults participate in the design process suggests the value of informal socializing (Davidson and Jensen 2013).
Social connection as a motivator both to accept technology and to participate in research	Dialog to draw on user's knowledge: plan ample time for chatting and suggest gaining rapport with users	Designer/researcher should only take a facilitating role. Participating in a design process will make older adults feel a stronger sense of community through a sense of civic pride and empowerment (Demirbilek 1999). Researchers can learn a lot from the conversation with or between older participants on related subjects if ample time is set aside for these discussions, anecdotes, and tangents.
Importance of personalized training	Tailor presentations and examples to user group	When level of experience with digital technologies differ between participants, it is desirable to address their differing needs such as providing more tie for questions and answers (Orzeszek et al. 2017).
CHALLENGES WITH USABILITY		
Technology acceptance factor identified	PD practice/ strategy or approach suggested	Notes/ explanation
Comfort / discomfort Ease of use	Cooperative evaluation Going through the motions: envisioning, enacting, future scenario storyboards (Sanders et al. 2010) Continue to design when the project is already in use	User testing can identify issues of usability but earlier in the design process, walking through the use-case scenario with end users can already support usability. Design and collaboration can continue to develop the product with continued ongoing user contact to increase appreciation and performance of the system (Dittrich et al. 2002).
DOUBTS AND APPREHENSIONS		
Technology acceptance factor identified	PD practice/ strategy or approach suggested	Notes/ explanation
Apprehension of novelty Fear of detrimental effect on health and wellbeing	open communication	PD is based on elements of democracy and mutual respect (Muller et al. 1993; Smith et al. 2017; Spinuzzi 2005).
Difficulty remembering how to use	Create a scaffolding in which to introduce the designed interactions	Orzeszek et al. (2017) explains that older adult's mental models of user experience interaction with ICT technology differ from the mental models of younger people, and suggests including older adults (Orzeszek et al. 2017).

In the next chapter, we will describe how we use the methods suggested in Table 22 in the Design Phase of this work.

Conclusion

This investigation has identified several barriers which block an important subset of older adults from the potential positive impact of wearable sensing and monitoring technologies. These barriers, at least in part, contribute to the relatively low technology acceptance of wearable monitoring technologies among older adults. This investigation has also pointed to certain facilitators which supported and motivated older participants of this study to interact with the technology probe provided. These barriers and facilitators indicate factors of technology acceptance important to address when designing for inclusion of this diverse user group. To this end, a codesign strategy is proposed to be used in the development and design of future wearable sensing and monitoring technologies for this user group. Table 21 summarizes the codesign strategy suggested. In order to increase the adoption of promising wearable technology among older adults, members of that diverse community should be included to participate in the design process.

Part Three

DESIGN

Our Exploration phase yielded many useful insights. In chapter four, we found behavior change strategies which motivated increased physical activity among older adults. In chapter five, we described an exploratory field study which helped us understand which personal traits potentially affect engagement in physical activity. Finally, in chapter six, we proposed methods of codesign which should address the barriers older adults face to engage in research toward the development of technological behavior change solutions. Armed with these insights, we embark on the design phase of our overall design research process.

Here, in part 3 of this thesis we describe how the findings from our exploration phase converge into a design process. We created two mobile applications which will serve as the design probe in our evaluation phase. The mobile applications aims to motivate increased physical activity among older users and to this end we implemented the behavior change strategies indicated in the results of the study described in chapter four. In order to create these mobile applications, we implemented the methods suggested in chapter six and took a codesign approach to the design of this mobile application. This chapter will describe in more detail the design of the REACH HealthyTogether Application.

CHAPTER SEVEN

Design of the REACH HealthyTogether Application

To enable research on how to create personalized behavior change solutions for older adults, we need to design probes which facilitate important in-context research. Here, we will describe how we created design probes in which we implemented promising behavior change strategies, previously identified in chapter four of this thesis. The development of these probes is still a challenge as many older adults' face barriers to technology acceptance. To overcome identified barriers to technology acceptance and create the necessary design probes, we apply codesign methods identified in chapter six to create a design probe in the form of a mobile application aimed to stimulate increased physical activity among older adults. This design probe will be valuable in conducting further research towards a better understanding of how to personalize behavior change strategies, described in part 3 of this thesis. In this chapter, we will describe our codesign process, resulting mobile application and subsequent evaluation before reflecting on the efficacy of the design process strategies proposed in the previous chapter.

This chapter is based off of work presented in

REACH EU publication Deliverable D26: Final mock-up version of REACH system (reach2020.eu/?page_id=1190)

Introduction

As we age, we tend to adopt a more sedentary lifestyle, which can exasperate the symptoms of frailty and other chronic conditions (Davis et al. 2011; De Rezende et al. 2014). In recent years mobile and wearable technologies have been developed to support healthy habits such as increased physical activity. There is an important need to investigate how to use these technologies to create personalized behavior change solutions for older adults. In this chapter we will describe the design process of a design probe in the form of a mobile application which will facilitate in-context research towards personalized behavior change solutions for older adults. The design of this probe will be based on insights gathered in the exploration phase of this work; the codesign process used was presented in chapter six and the behavior change strategies implemented in the probe were derived from insights gathered in chapter four.

Related work on Codesign Towards the Development of Technological Design Probes

However, an important subset of older adults is still excluded from the benefits of these behavior change solutions due to the barriers they face to technology acceptance (Chen and Chan 2011; Mitzner et al. 2010; Valenzuela et al. 2018). To enable further investigation into behavior change strategies, we need to develop design probes, which are usable for older adults with limited technology acceptance, with which we can conduct in-context investigations. Yet how to design such a design probe remains a challenge.

Despite available accessibility guidelines many older adults who have limited experience with digital technology still face barriers to the acceptance and adoption of mobile technologies designed to motivate increased physical activity (Lee et al. 2020). A recent literature review of 52 research articles resulting in 434 guidelines to design touchscreen applications for older adults, by Nurgalieva et al., found that despite the number of contributions in this field, there is still little known about how to

translate these research findings into actionable design recommendations (Nurgalieva et al. 2019). Though we recognize the value of these guidelines as a starting point for considerations when designing mobile technologies for older users, these guidelines mainly focused on the user's limitations (Nurgalieva et al. 2019) so that developers miss valuable insights into making an application not merely usable for older adults but relevant to their day to day lives. Another systematic literature review mapped barriers and solutions to technology use and interaction revealing that older users have very different requirements than younger users (Dodd, Athauda, and Adam 2017). There is thus an important need to investigate design processes which address barriers to technology acceptance towards the development of important healthy lifestyle stimulating technologies.

In order to design mobile applications which are usable and relevant to the highly diverse older adult user group, we need to gain a better understanding of the specific needs and challenges, wants and values of a particular group of users beyond general accessibility guidelines. Codesign processes involving the end users have been effective in empowering the user to communicate their needs and values beyond their limitations (Davidson and Jensen 2013; Demirbilek and Demirkan 2004; Iversen et al. 2017; Lindsay et al. 2012). A codesign process aims to involve end-users throughout the design process, in an active collaborative way. Codesigning technological devices together with older users has been shown to yield design ideas which were deemed creative and useful by participants of the process (Davidson and Jensen 2013). Forms of codesign like participatory design can empower the user to advocate for their needs and values within the design process, enriching the resulting concepts beyond addressing only user's physical limitations (Davidson and Jensen 2013; Demirbilek and Demirkan 2004; Iversen et al. 2017; Lindsay et al. 2012). In this way codesign process has even been shown to contribute to technology acceptance (Valk et al. 2018). Furthermore, experienced authors advocate for human centered or some level of codesign in order to meet the specific needs and challenges of older adult users (Dodd et al. 2017). It is clear that there are many advantages to the codesign approach towards creating mobile applications suitable for older users.

However, it is still not clear how a codesign approach can support the creation of mobile technologies appropriate for older adults, because carefully documented processes are lacking. From their systematic review Nurgalieva et al. found that only 15% of the articles reviewed validated their recommendations (Nurgalieva et

al. 2019), which is indicative of a larger trend towards experimentation with design processes which lack the follow-through to evaluate resulting designs, leaving little indication about the actual success of that process. Authors Xie et al., showed that a codesign process could even facilitate intergenerational collaborations between older adults and children (Xie et al. 2012). Unfortunately, no mention was made about whether the resulting designs were developed and evaluated so that the true effectiveness of the codesigned results remains ambiguous. Sigridur and Sins, 2018, provide a positive example of a collaborative design process involving both users and care providers to create a home grocery delivery application for older adults (Sigridur and Snis 2018). Yet, they too do not provide a clear in-context evaluation of the resulting application design. Authors Harrington et al. describe an experience based redesign process of activity stimulating applications; prior to their design collaboration, they assigned participants commercially available mobile activity stimulating applications (Harrington et al. 2018). The older user's experience with the assigned mobile application was used as input and a starting point for the codesign process (Harrington et al. 2018). This work yielded guidelines on how to implement experience-based codesign, yet again, the design results were not developed and evaluated. Without an evaluation of the design resulting from the codesign session it is difficult to know just how effective such an approach is for the development of appropriate technologies for the very diverse older adult community.

Current literature rarely describes any in-context evaluation of design concepts resulting from collaborative design processes involving older users so that it remains unclear to what extent these codesign processes are useful in the development of digital behavior change interventions for older users. So, in this chapter we will investigate how a suggested codesign strategy, presented in chapter six, can be used to create a design probe implementing strategies suggested in chapter four, in the form of a mobile application for older adults. To this end, we will first describe how we applied this codesign strategy to the redesign process of an existing mobile design probe to create an application for older adults to use outside of a workshop or laboratory setting. We will also describe the resulting mobile application and subsequent evaluation of that application. Finally, we will reflect on to what extent our design process addresses the identified barriers to technology acceptance (identified in chapter six), in order to contribute a practical example of an inclusive codesign process towards the development of behavior change interventions.

Method

The aim of this design process was to create a design probe which embodied the strategies presented in chapter four, to be used in a future field study to investigate the effectiveness of behavior change strategies. We were also curious to gain a better understanding of how a codesign process could address the specific needs and challenges of older adults when designing a mobile application aimed to motivate increased physical activity. To this end we took an iterative collaborative approach, as suggested in the previous chapter, to redesign the original HealthyTogether application. Then we reflected on the usefulness and practical implementation of the suggested codesign methods.

In this iterative codesign process we first conducted a collaborative redesign process together with a small focus group of older adults to redesign an existing activity stimulating mobile application. We then deployed the resulting application probe to a larger number of older adult participants in order to see if the application would be usable outside of the workshops led by the research team and in the context of daily living of the participants.

Design Process

As suggested in chapter six we conducted an iterative collaborative design process to create a behavior change intervention for older adults in the form of a mobile application. To this end we chose to redesign an existing working application prototype, the HealthyTogether application, as we wanted to use the resulting design probe, or resulting mobile application, in a similar study as the original application. The original mobile application was first developed as part of a larger study investigating the effectiveness of different behavior change strategies to motivate increased physical activity among university students (Chen and Pu 2014).

Codesign Strategy

In the previous chapter we have identified certain factors relevant to technology acceptance among older adults who participated in that explorative study. These factors could be organized into four themes; technology potential for older users, influence of social connection, challenges related to usability, and doubts and

apprehensions about technology. From a critical theoretical reflection on each of these themes, the previous chapter suggested codesign methods to address each factor of technology acceptance. The methods suggested from the analysis in the previous chapter are summarized in Table 23: Summery of identified factors of technology acceptance and corresponding codesign method (to find more details on this refer to the original Table 22: Summary of the suggested PD methods and approaches for addressing technology acceptance among older adults organized by thematic cluster). The collaborative redesign process described in this chapter was closely inspired by the methods suggested.

TABLE 23: SUMMERY OF IDENTIFIED FACTORS OF TECHNOLOGY ACCEPTANCE AND CORRESPONDING CODESIGN METHODS

THEMES	*IDENTIFIED TECHNOLOGY ACCEPTANCE FACTOR*	*CODESIGN STRATEGY OR APPROACH SUGGESTED*
TECHNOLOGY POTENTIAL	Self-efficacy	Self-decision to empower older adults to take an active design role in the development of new technologies.
	Perceived benefit	Co-decision for user inclusion in various steps of the design process beyond only ideation
	Customization of technology intervention	Drawing/paper modelling as a way to make low fidelity paper prototypes Design for flexible use
INFLUENCE OF SOCIAL CONNECTION	Peer to peer social recognition	Group workshop ideation setting
	Social connection as a motivator	Dialog to draw on user's knowledge plan ample time for chatting and suggest gaining rapport with users
	Importance of personalized training	Tailor presentations and examples to user group
CHALLENGES RELATED TO USABILITY	Ease of use and comfort	Cooperative evaluation and Going through the motions (envisioning, enacting, future scenario storyboards) (Sanders et al. 2010)
DOUBTS AND APPREHENSIONS	Apprehension of novelty and Fear of detrimental effect on health and wellbeing	Open communication
	Difficulty remembering how to use	Providing a scaffolding in which to introduce the designed interactions

In this collaborative redesign process, we worked with a focus group of five older adults with various degrees of experience with technology, recruited via the local senior community center. Three iterations were made before the final prototype of the application was ready to be evaluated by a larger group of older adult participants.

In iteration one we built on existing accessibility guidelines and redesigned the application to adhere to these prevailing guidelines. To this end we used Adobe XD to make a quick experienceable prototype of the application, as seen in Figure 19 and 20. This tool allowed us to make changes to the original application so it would better adhere to available accessibility guidelines and present this to our users in subsequent iterations, in a time effective manner.

In order to be able to use the redesigned application in a similar study as the original application, our research team came up with certain study related requirements for the redesigned design probe.

1. Design probe application should be usable for older adults with limited experience with digital technologies to such an extent that participants use the application on about a daily basis.
2. In order to compare two different motivational strategies, there would need to be two versions of the design probe application, as there were of the original HealthyTogether prototype.

Then we facilitated a focus group discussion about the initial redesign to ease participants into the collaborative process, by presenting a clickable prototype of our initial redesign. When focus group members seemed comfortable, we moved on to asking them to interact with the clickable prototype we made in Adobe XD (a vector-based application for wireframe creation and app development), in order to identify specific navigation and usability issues. Finally, we presented several paper prototypes which were used as input for further discussion and creative ideating. The findings from this collaborative process were implemented to make a working version of the redesign application, which was used in a pilot study with the participants from the collaborative design focus group, before a final iteration was used in the evaluation study.

In the discussion section we will reflect on the codesign process, the changes necessary to make the original application more suitable for older user, and the in-context evaluation of the resulting mobile application.

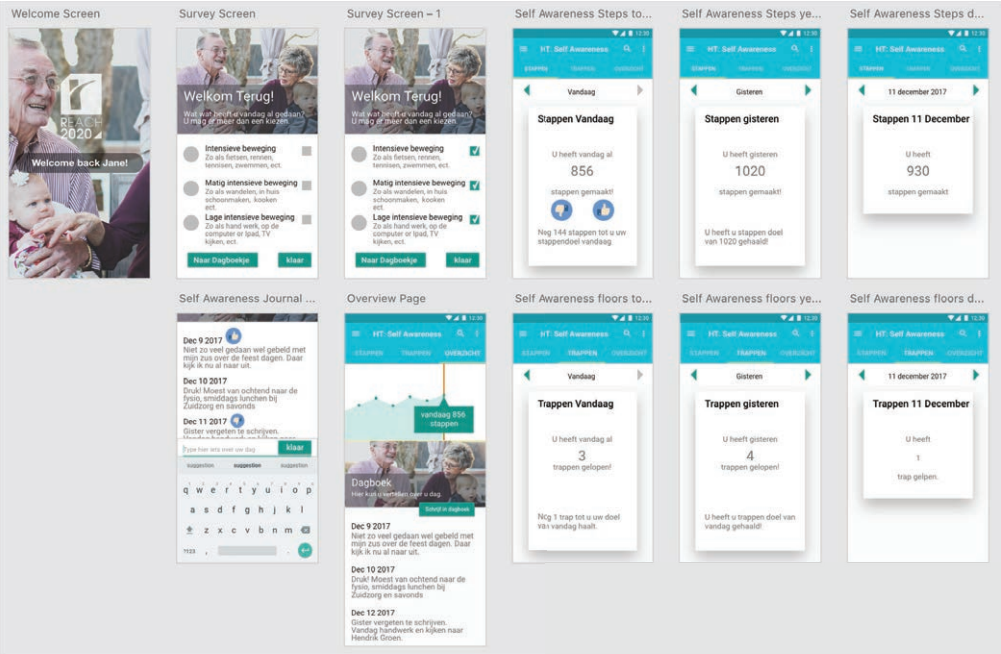


Figure 19: Initial wire frames created in Adobe XD

Design Strategies to Implement in the Design Probe

The investigation described in chapter four yielded certain behavior change strategies that indicated to be promising for older adult users, replicated in Table 24. We knew that the initial aim of the design probe would be used in an A/B test, we decided to select only two of the indicated strategies to develop into the design probe. For our purpose we selected self-awareness and social fitness for this purpose because these strategies are already prevalent among commercially available physical activity stimulating mobile applications (Lyons et al. 2014; Middelweerd et al. 2014). In addition, social connection even through a mobile device can have positive effect on the welling of older adults (Visser, Vastenburg, and Keyson 2011) and self-awareness seemed a fitting compliment.

Figure 20: Simplified visual interface

TABLE 24: PROMISING BEHAVIOR CHANGE STRATEGIES IDENTIFIED IN CHAPTER FOUR

VALUE CLUSTERS: PROPOSED STRATEGIES	PERSUASIVE CATEGORIES*	COMBINED STRATEGIES*
SOCIAL FITNESS	*Primary task support and social support*	*Social-facilitation, self-monitoring, tunneling, personalization,*
IMPROVED CARE	Primary task support and credibility support	Expertise, suggestions, reward, authority
PRIZE	Primary task support and dialogue support	Tunneling, personalization, suggestion
SELF-AWARENESS	*Primary task support and dialogues support*	*Self-monitoring, personalization, expertise, real-world feel, suggestions,*
FUN	Primary task support and dialogues support	Tunneling, personalization

* Persuasive categories and principles from Oinas-kukkonen and Harjumaa 2009

In the next section we will show how the original application which we used as input for the redesign process also had different versions with different levels of social interaction or cooperation built into it.

Description of Original Application: What are we working with?

The HealthyTogether application, as pictured in Figure 21, visualized physical activity data collected from a commercially available wearable activity tracker and aimed to compare three different motivational strategies; collaboration, competition and a hybrid of these two. Users of each of these three versions of the application can see their physical activity as compared to the activity of the user they were paired up with (represented by the horizontal orange and blue bars in Figure 21) throughout the day. Physical activity was measured in terms of steps taken and flights of stairs climbed, using a wearable Fitbit tracker and visualized in the HealthyTogether application. In each version of the application the user tries to earn badges representing different achievement goals. In the competition version of this application, the user needs to earn each of their badges by reaching their steps goal independently and compete with their counterpart user to earn more badges in a shorter amount of time. In the collaboration version of the application, users collaborate with their counterpart as each contribute equally towards the shared activity goal and badges. In the Hybrid version of the application, the users own activity contributes most towards earning their badges, yet they also need their counterpart to contribute in order to earn their badge. Paired users could also send each other messages by selecting either the "Cheer friend" or "Taunt friend" buttons. Users can keep a log on various aspects of their day such as mood and food and navigate through data from previous days by using the top navigation bar.

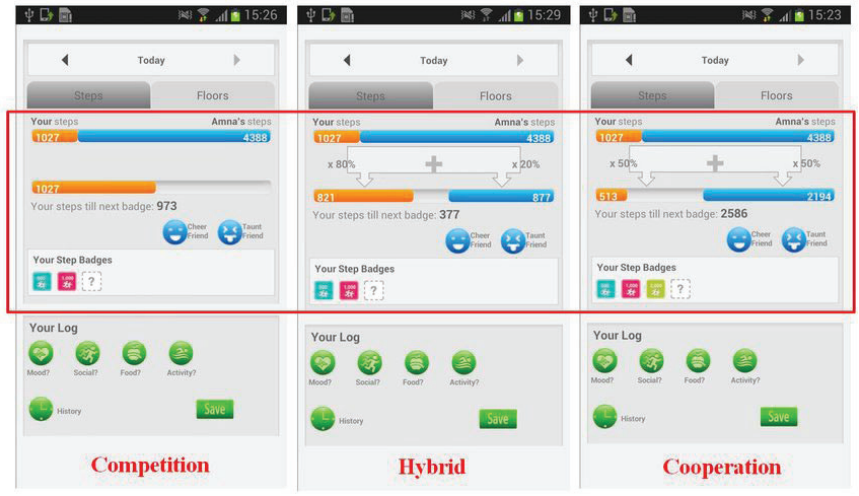


Figure 21: Original HealthyTogether application (Chen and Pu 2014) used as a starting point for collaborative redesign process described in this chapter

From our literature research and from examining existing guidelines we anticipated several changes to the original design of this application. Foremost the original application does not satisfy visibility guidelines due to the small font size and the relative lack of contrast between the color of the text and the color of the background the text is visualized on. In addition, we anticipated that the visual presentation of this application would be too busy for older adults with limited experience with digital technologies and this might lead them to feel overwhelmed. Our first iteration would thus focus on redesigning the original HealthyTogether application according to accessibility guidelines as initial input for the collaborative redesign process.

Evaluation of Resulting Application

To better understand whether the redesigned application is indeed appropriate to be used by older adults, we conducted a five-week in-context evaluation. To examine the transferability of this application we recruited more older adults from the local senior community center to participate in the evaluation of our resulting design probe. Older adults were provided with a commercially available wearable activity tracker (the Fitbit Flex 2) and smartphone (Mi A1) to use for this investigation. Participants were given time to wear the activity tracker and get used to the smartphone over a period of four weeks before the start of the evaluation. The average daily physical activity in terms of steps for each individual from this period would also inform highly personal activity goals for each participant. Then participants were asked to track their daily physical activity using the redesigned application over the course of the five week in-context evaluation. At the conclusion of the study, participants were encouraged to share their experiences with the resulting design probe with the researchers during a closing workshop and through answering a few short questions on a hardcopy questionnaire, including how frequently they used the resulting design probe, or resulting redesigned application, and their level of confidence with mobile technologies on a five-point scale. We also asked participants to compare the resulting redesigned application to the Fitbit application, which was used by the resulting application for data collection purposes, as it is one of the current market leaders in this field.

The purpose of this evaluation was to see if the collaborative design approach together with following existing guidelines to design a mobile application would adequately address the usability needs of older adults. Here we aim to contribute practical procedural knowledge on how to create mobile applications which are more

inclusive toward the older adult population many of whom have limited experience with digital technologies yet could benefit from these new lifestyle related solutions. The results of this in-context evaluation will be examined in the discussion section of this chapter.

Results of the Collaborative Redesign Process and Subsequent Evaluation

In this section we will look at the results of each of the three iterations and the application resulting from the collaborative redesign process before we present findings from the evaluation study.

Iteration One: Redesign According to Guidelines And Research Requirements

The original application prototype compared a competition, a cooperation and a hybrid behavior change strategy to each other. However, unlike the original authors of the HealthyTogether application we were interested in comparing cooperation to self-awareness instead of cooperation to competition, because, from our experience described in chapter four, we envisioned these strategies would be more appropriate for our specific target user group. In this very diverse group of older users, it was very important to us not to discourage people from doing physical activity by putting them in competition so we opted to compare cooperation as seen in the original application to self-awareness, because it is one of the most basic and often used behavior change strategies towards increased physical activity (Lyons et al. 2014; Middelweerd et al. 2014).

To increase the usability of the application we aimed to redesign it to adhere to available accessibility guidelines. We did this by simplifying the visual content displayed, narrowing action options to only those anticipated to be important to usability supporting the research goals we had in mind. As we would not be testing the effect of rewards, we chose to forgo the earning badges system as this added a level of complexity not strictly needed for the usability of the application. The log was removed for the same reason. We maintained the stickers which allowed participants

to communicate through the application with their counterpart as this was an integral part of the cooperation strategy. The participants using the self-awareness version of the application would be able to use the stickers to simply record if they thought they had done well or if they felt they could have done better. We used simplified language in addition to icons and large text font to satisfy accessibility norms.

The representation of the cooperation version of the original application prototype still put a visual emphasis on comparing the number of steps each of the collaborating users made. To us it still seemed that this could be discouraging to some people who would like to do more but due to personal circumstances or health reasons would consistently contribute less steps to the joint step goal. This is especially a concern among such a diverse group of participants, with very different levels of physical abilities. Thus, we decided to explore ways to change this data visualization which did not distinguish how many steps each user contributed to their joint step goal, Figure 22.

Figure 22: Screenshot of different iterations of progress visualization

In this first iteration we redesigned the original application to better adhere to existing accessibility guidelines and created a clickable prototype which was usable on a smartphone for demonstration purposes, Figure 20. The outcome of this first iteration served as a starting point for upcoming codesign activities.

Iteration Two: Codesign Activities Provide Input to Redesign

The interactive prototype resulting from our initial redesign process, Figure 20, was used as the starting point for the codesign sessions which shaped the second iteration of this application redesign. This second iteration was designed through several codesign activities including focus group discussions, interactions with the existing prototype and ideation using paper prototyping. Input from these sessions was used to create a working second iteration of the redesign application, which was then pilot tested with the participants of the codesign process before it would be evaluated by a wider group of older users.

Five older adults, three men and two women with an average age of 79.4 with differing levels of self-reported confidence were recruited via the local community center to participate in our collaborative redesign process, see more details in Table 25. This group of collaborators, participated in codesign activities including focus group discussions, interactive walk throughs, and ideation.

TABLE 25: COLLABORATIVE REDESIGN PARTICIPANT DETAILS

GENDER	*AGE*	*SELF-REPORTED SMARTPHONE CONFIDENCE*	*SELF-REPORTED SMARTPHONE CONFIDENCE ON A FIVE-POINT SCALE*
Male	90	A little apprehensive or confused	3
Male	84	Somewhat confident	4
Male	83	Somewhat confident	4
Female	70	Very confident	5
Female	70	Never used a smartphone	1

Focus Group Discussion

We see the importance of allowing older adult participants the time to get comfortable with the subject matter and comfortable voicing their opinion in the group. For this reason, we started our collaboration process off with a focus group discussion about the proposed redesign. After presenting the first iteration of the redesigned application we asked questions about both hardware (anticipated ease of charging, where would you keep this device?) and the proposed software (is the text legible to you? Do you anticipate wanting to send and/or receive messages?). In addition to the discussion about the mobile application, we also brought in the proposed phone and activity tracker we were interested in using for the larger evaluation study to show the clickable prototype on the exact screen participants would be using during the evaluation. We discussed screen size and comfort of the wearable fitness trackers. We even brought in a system for wireless charging, but it was deemed unnecessary, by focus group participants.

Interactive Walk Through and Observations

To identify specific usability and navigation issues we asked participants to walk through a set of interactions identified as likely to come up during actual use of this application. These walk-through scenarios focused on both hardware and software interaction, such as; "could you charge the phone and then navigate to the steps you took today?". The focus group was made up of people with diverse levels of experience with digital technologies so we asked a member of the panel who had very little experience with digital technology to hold the smartphone provided and navigate through the application while others in the focus group looked on and supplied advice or questions. The research team took note of this interaction among potential end users and observed which navigation elements and/interactions could be improved upon.

Paper Prototyping and Ideation

Participants of the focus group are presented with a selection of different interface iterations of this application, as seen in Figure 22. Participants were then asked to annotate these options in several ways to show which option they personally found most easy to read, which activity visualization they liked best and least, Figure 23. In addition, to the prefilled in options there were several blank screens provided where the focus group was asked to ideate how they would personally prefer the application to look, Figure 23.

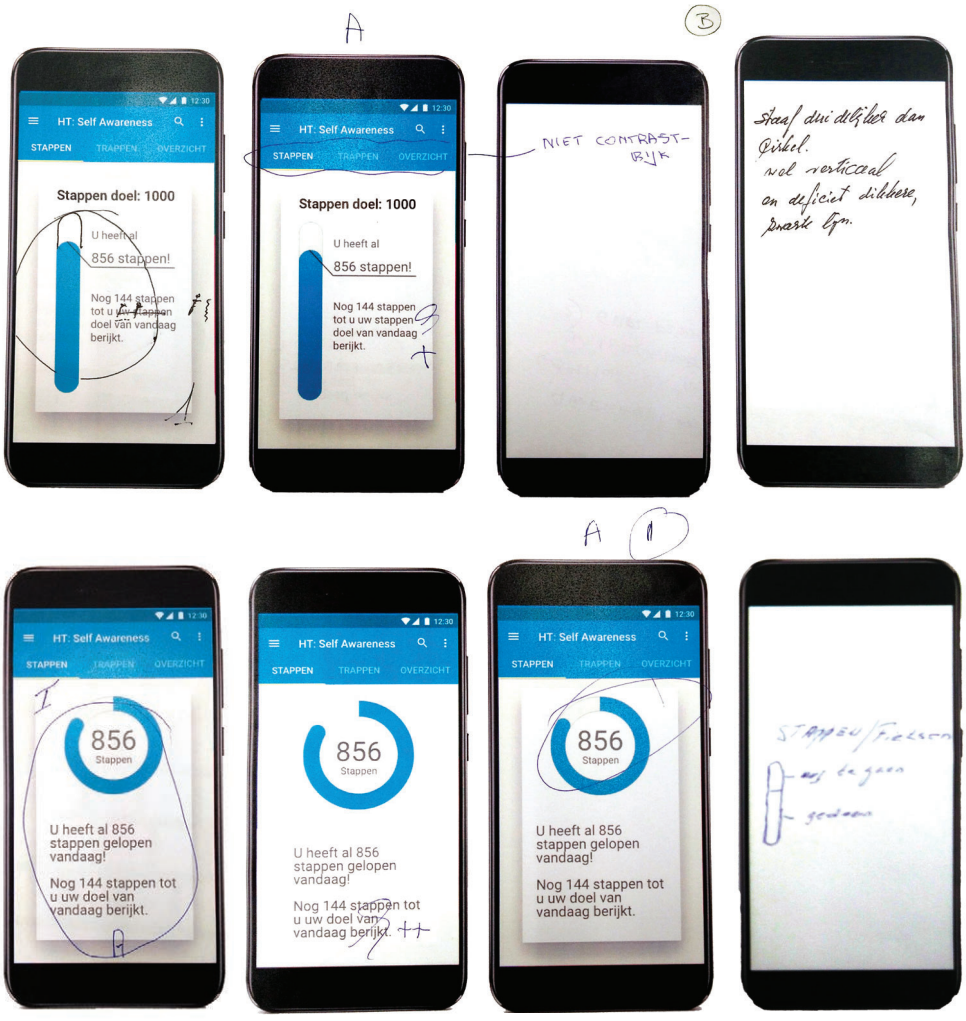


Figure 23: Examples of annotated interfaces and ideation results from the codesign session

Researcher observations and the results from these collaborative design activities, were consolidated to inform the second iteration of the redesign. Figure 24: Process images of the application redesign into iteration two shows process images of annotations being made to iteration one after the results of the codesign process were analyzed to provide input for the development of the second iteration of the redesigned design probe.

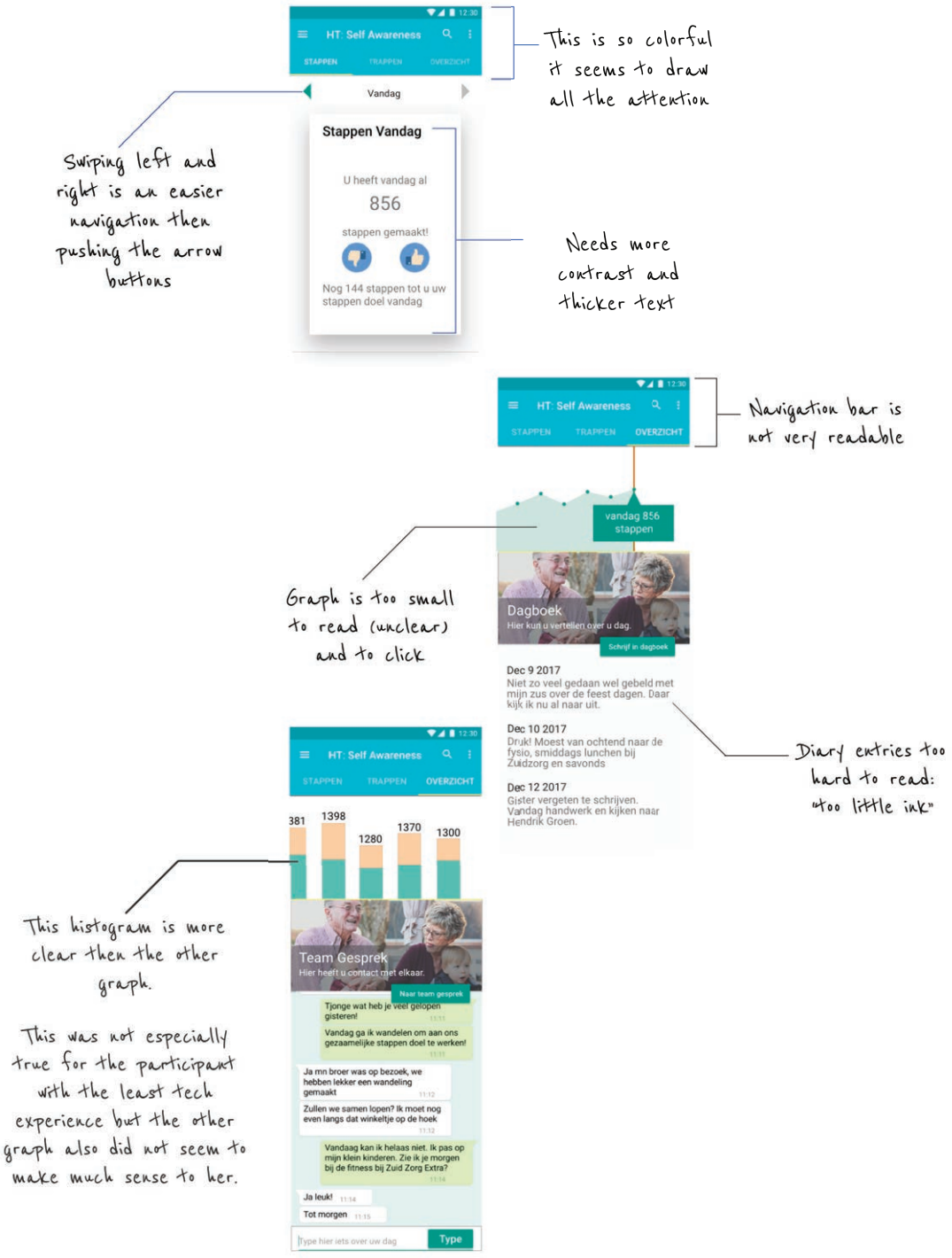


Figure 24: Process images of the application redesign into iteration two

Pilot Study of Design Probe Iteration Two

We used results from the codesign activities to program a fully functional second iteration of the application, which could collect and visualize measured physical activity data from the Fitbit wearable activity tracker. Our application was built to work in conjunction with the Fitbit wearable activity tracker and pull physical activity data from the Fitbit application, which needs to run in the background for our application to work. This functional second iteration was to be used in a pilot test with codesign participants in preparation for the larger evaluation of this redesign.

The aim of this pilot study was to find and correct any bugs which may still be present in the working application prototype and to make sure the in-context evaluation could be run smoothly. For the pilot test the members of the focus group were provided with Mi A1 smartphones and Fitbit Flex2 wearable activity trackers and asked to use this mobile application and accompanying activity tracker for several days in their normal context of living. Participants provided their feedback to researchers in focus group discussion following the pilot test of the second iteration of the application.

From this pilot user test, we found we needed to make certain small adjustments to our interface but that our system of data collection and representation worked reliably. We addressed the concerns raised in the pilot study in our third iteration of the application redesign.

Iteration Three: Resulting Redesign

The resulting design probe, the REACH HealthyTogether application, was the result of an iterative collaborative redesign process and builds on accepted accessibility guidelines with valuable user input. The color pallet, font, type size and wording used were derived from existing generalized accessibility guidelines. Whereas the interaction, navigation, visual representation of data and general interface design, was inspired by the collaborative redesign process.

The REACH HealthyTogether application has two very similar versions to facilitate a comparative research study, in much the same way the original application did. The first integrated the self-awareness behavior change strategy and the second integrated the cooperation behavior change strategy, see Figure 25 and Figure 26 respectively. In both versions of the application the circle graphic visualizes progress

towards a highly individualized physical activity goal, expressed in terms of total number of steps taken a day. However in the self-awareness application, Figure 25, the circle graphic visualizes the users own progress towards their personal goal while in the social cooperation application, Figure 26, the circle represents the total progress of the user and another user they were paired with towards a combined daily activity goal. The daily goals for the pairs of cooperation-version users, is the sum of the two individual user's goals. In this progress visualization no distinction is made on how much of a contribution towards the shared goal each user has made. In the history tab, users can find an overview of their progress towards their daily activity goals over several days, in both applications. Those cooperating in user pairs, can find more information on their personal progress here. The "could improve" and "good effort" sticker buttons navigated users of the self-awareness version of the application to an activity log, where they could record their thoughts by typing or choosing prewritten messages related to which button they used. The "taunt friend" and "cheer" friend navigated the users of the cooperation version of the application to a messaging feature, where they could communicate with their partner, by typing a message or choosing a prewritten message related to the message on the button they chose.

The REACH HealthyTogether application was the third iteration resulting from a successful collaborative redesign process. In the next section we will describe how this resulting application was evaluated by the target user demographic of older adults.

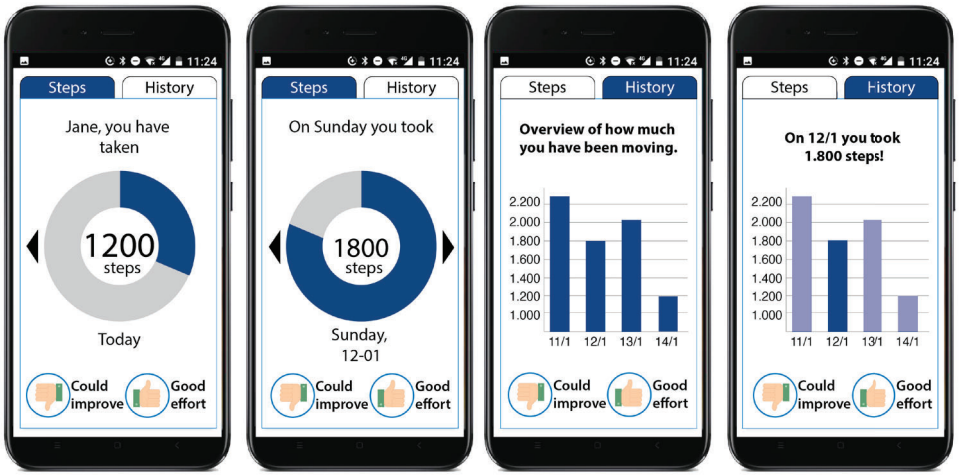


Figure 25: Intervention application for the self-awareness condition

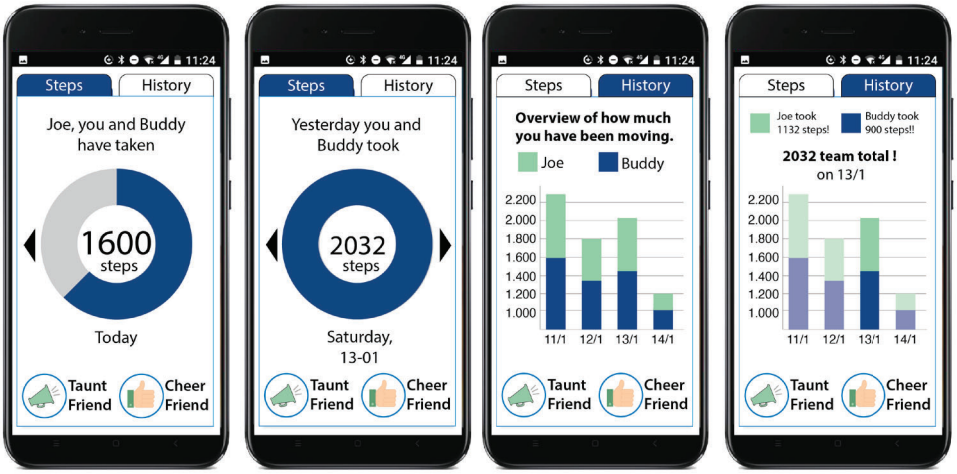


Figure 26: Intervention application for the cooperation condition

Results of Application Evaluation Study

The REACH HealthyTogether application is the result of the iterative collaborative redesign process, described above, and aims to motivate increased physical activity among older adult users. To investigate whether the REACH HealthyTogether application is suitable for the older adult target users, we conducted a five week in-context evaluation of this application using a fully functioning application prototype.

Fifty-three older adult members of the local community center used the provided application over a five-week duration. A few weeks prior to the in-context evaluation study we provided the older adults with the research issued smartphones (Mi A1) and wearable tracking devices (Fitbit Flex 2), to give them a chance to get familiar with these objects before introducing the REACH HealthyTogether application. The evaluation study started with a workshop in which the research team introduced the REACH HealthyTogether mobile application to the older adult participants. Participants were asked to use the application to track their physical activity over the next five weeks. At the end of the evaluation each study participant was asked to answer a few questions describing their experience with the mobile application.

Of the 53 older adults who participated in this evaluation, 40 were female and 13 were male, with an overall mean age of 72.38 years. Of the 51 participants who answered the final questionnaire 46 reported they used the REACH HealthyTogether application every day, details described in Table 26.

TABLE 26: HOW OFTEN DID EVALUATION STUDY PARTICIPANTS LOOK AT THEIR STEPS?

Once or twice in the past few weeks	2
Several times a week	2
About once a day	20
Several times a day	26
other	1

As mentioned above, in order for our working application prototype to visualize real time measured physical activity data, the Fitbit mobile application needed to be running in the background. Later the research team asked evaluation study participants which application they preferred; the Fitbit application or the REACH HealthyTogether application? 10 participants reported they preferred the Fitbit application and 15 reported they prefer the REACH HealthyTogether application, while 26 reported they liked both applications, Table 27.

TABLE 27: WHICH MOBILE APPLICATION DID STUDY PARTICIPANTS PREFER?

Both	26
REACH HealthyTogether application	15
Fitbit	10
Neither	2

According to our survey results, participants found both the Fitbit application and the REACH HealthyTogether application to be "clear" and "quick" so they could perceive their activity information right away. Also, two participants mentioned that these two applications complemented each other because they offered a different experience. Overall many who preferred the Fitbit application pointed out it was able to measure a higher diversity of activities, such as cycling and sleeping and was thus able to provide more information. However, people who preferred the REACH HealthyTogether application described it as easy to use more relevant to them and their goals and more personal. They also cited social aspects of the REACH HealthyTogether application as reasons they preferred it over the Fitbit application. Interestingly, some of the function's participants gave as reasons why they preferred the REACH HealthyTogether application, are also present in the Fitbit application, such as some social features and a graphical overview of personal activity over time.

We compared participants self-reported confidence with smartphone technology (on a five-point scale, where 5 = very confident) to the application they said to prefer; 1) Fitbit application, 2) REACH HealthyTogether application, 3) both or 4) neither, see Table 28 for more details. These results seem to suggest that older adults with lower technology related confidence, prefer the REACH HealthyTogether application, while participants with higher technology related confidence seem to generally prefer the more multifaceted Fitbit application, which resonates with our qualitative analysis results.

TABLE 28: HOW DOES APPLICATION PREFERENCE RELATE TO PARTICIPANT'S SELF-REPORTED CONFIDENCE RELATED TO SMARTPHONE USE?

APPLICATION PREFERENCE	AVERAGE SELF-REPORTED SMARTPHONE CONFIDENCE ON A FIVE-POINT SCALE
Fitbit Application	4.33
REACH HealthyTogether application	3.54
Both	3.67
Neither	NA[a]

[a] There were only two people who reported they preferred neither application. They had a self-reported smartphone confidence 5 and a 1.

In the next section we will discuss these and our other findings and their implications further.

Discussion

In this section, we will use our codesign process and the results of the evaluation study, to reflect on to what extent this design process addresses the factors of technology acceptance identified in chapter six, and whether or not we were successful in creating a design probe for our further research into behavior change strategies.

Reflections On Our Iterative Collaborative Redesign Process

From previous work (C. Valk et al. 2018) certain technology acceptance factors were identified. Codesign practices were suggested to address each of the corresponding technology acceptance factors. Table 29 summarizes how we implemented each of the suggested codesign practices into the iterative design process we conducted to redesign the original HealthyTogether application, into a design probe we will use for further research. Below we will reflect on how we used the suggested methods to enrich each activity in our codesign process.

TABLE 29: RELATION OF CODESIGN APPROACH TO THE METHODS SUGGESTED BY VALK ET AL. 2018 IN CHAPTER SIX ORGANIZED BY THEMATIC CLUSTER

	CODESIGN STRATEGY OR APPROACH SUGGESTED	FOCUS GROUP DISCUSSION	INTERACTIVE WALK THROUGH AND OBSERVATION	PAPER PROTOTYPING AND IDEATION	PILOT STUDY OF ITERATION TWO
TECHNOLOGY POTENTIAL	Self-decision	X	X	X	
	Co-decision	X			X
	Drawing/paper modelling			X	
INFLUENCE OF SOCIAL CONNECTION	Group ideation	X	X		
	Unstructured Dialog	X		X	X
	Tailor presentations and examples		X		X
USABILITY CHALLENGES	Cooperative evaluation and enacting	X	X		X
DOUBTS AND APPREHENSIONS	Open communication about limitations	X	X	X	
	Providing a scaffolding to introduce technologies		X		X

Reflection on Focus Group Discussion

Our focus group consisted of members of the senior community center who were invited to join the focus group by a staff member of the senior community center, so that researchers did not select the participants themselves. We recognized the importance of building a good rapport with the focus group volunteers so that each would feel comfortable voicing their opinion in further codesign activities. To achieve

this level of comfort in the group we spoke in formally but politely, sat down in a circle instead of presenting, acknowledged that current health tracking applications can be difficult to interact with because they are not designed with older users in mind and frankly explained both the aim of the codesign process as well as our motivation for it. This open communication about the limitations of current technologies started the conversation off in the right direction, allowing participants of the focus group to more readily admit their frustrations and apprehensions about technologies. We are fortunate to conduct research in a country where the prevailing culture emphasizes frankness, which might help participants feel comfortable voicing their opinions. Focus group participants seemed to mirror our demeanor and seemed very open and eager to begin, which was a very important starting point for this codesign process.

The initial redesign, the clickable demonstrator of iteration one (Figure 20), was brought in as a conversation starter. The group setting here was important as focus group members interacted with each other as well as with the researcher. We were able to gain valuable insight into participants' likes and dislikes as well as a deeper insight into participant's previous experience with technology as the focus group members chatted amongst themselves.

The focus group gave their opinions on the first iteration and discussed the provided hardware. From this discussion, our focus group participants came to collective decisions on the hardware choices for the proposed study. From this productive discussion we can see how valuable it is to empower each participant to voice their opinion and how useful these decisions are. Importantly we feel that it was largely the initial openness of the researchers and the framing of the design process as an open-ended question which led to this collaborative atmosphere. We would like to add to the codesign methods suggested in the previous chapter that explicitly giving the focus group members the role of expert or teacher and the designer the role of the student is beneficial to the overall process. we believe this to be beneficial as it reiterates to those less familiar with a design process that the designer is there to learn and that everything the focus group member says is inherently valid because they are the experts on their own experience. Instilling confidence in participants is key especially when working with people who have little experience or little confidence with digital technologies.

Reflection on Interactive Walk Through and Observations

As the focus group participant with the least confidence and experience with digital technologies walked through several scenarios other focus group members provided help, comments and suggestions. This turned the walk through into a group activity and again the dialog between the focus group participants was informative to researchers on the subject of which interactions were unclear as these took more time and discussion. In this way focus group participants were able to address usability challenges. When a particular navigation required during the interactive walk through proved challenging, focus group members were supportive in helping each other and weighed in with alternative navigation options or suggestions. The suggestions focus group participants supplied about navigation preferences were adopted into the final iteration. Again, in this activity, the methods suggested in the last chapter, such as empowering the user to help make decisions throughout the design process and facilitating group activities to enhance open communication dialog, were valuable to the development of the design probe. We strongly advise others conducting like investigative processes, to also use the walk-through or envisioning methods as usability challenges came up which did not arise from the previous group discussion. Using a variety of codesign activities was found to be useful as it allowed participants of the codesign process to examine the subject from different perspectives and also gave participants a variety of options as to how they were most comfortable communicating their opinion.

Reflection on Paper Prototyping and Ideating

In this ideation session focus group members annotated printouts of the first iteration of the redesigned application and were given the opportunity to draw their own design preferences. These low fidelity prototypes allowed focus group participants to iterate rapidly and through these annotations make suggestions to the overall design of the design probe. From the multitude of changes that were made to the first iteration of the redesigned application during the codesign process, it is clear that 'following accessibility guidelines' alone is not enough to create mobile technologies which are relevant and suitable for older adults.

In this codesign process, participants seemed to feel comfortable sharing their ideas and providing suggestions to the research team on how to improve the application. However, we found our participants preferred to verbally explain rather than draw their ideas. This is common in codesign sessions for most adult age groups, as people

feel more comfortable expressing themselves in ways, they are most familiar with; speaking and writing. Nonetheless, annotating the provided paper prototypes did seem to encourage participants to ideate more on the provided blank interfaces. In future, we would recommend expanding the paper prototyping tools to capitalize on this willingness to be hands-on to edit as a way to lead into idea generation.

Reflection on Pilot Study of Design Probe

Some time elapsed between the last codesign activity and the pilot study, as our research team needed time to code the data collection and visual interface so that it would be robust enough for use in a field test. Originally participants were excited to see how their suggestions were implemented into the working design but also researchers realized that due to the clickable prototype used before the presentation of a working mobile application was not as impressive to focus group members as maybe the researchers might have expected. None the less the focus group used the application and returned with very concrete feedback, such as typos and mistranslations. Besides feedback on the interface focus group participants provided the research team with very valuable insight into which questions and challenges might arise from daily use of these new devices. Researchers found that tailoring advise and examples to the individual were helpful to answer usability questions which could not be addressed in the software. Researchers realized that they would likely need to tailor presentations and onboarding documentation for the participants of the larger study as well. From the dialog between the focus group members and listening to them explain how to use the application to one another, researchers began to construct a scaffolding within which to introduce and explain the interaction of the redesigned application which would be useful for the participants of the larger intended study. Finally, the focus group members turned pilot study participants, advised the research team to create and provide a hard copy instruction manual specifically for the study participants which we thought was a great suggestion. Our codesign process yielded the design probe we intended, so now it remains to be seen if the resulting application was as successful in the in-context evaluation.

Discussion of the Evaluation Results

We conducted a five-week in-context evaluation to see if the REACH HealthyTogether application is appropriate for older adults to use in their everyday lives. The regular usage of the REACH HealthyTogether application (see Table 26 for details) indicates that the application is usable for older adults. Besides the use of the application, we also asked participants to reflect on the comparative advantages of the redesigned application and the existing Fitbit application. We made the choice to ask participants to compare the redesigned application to the Fitbit application instead of the original HealthyTogether application (Figure 21) because so many changes needed to be made for it to satisfy the specific accessibility standards of this user group, the comparison outcome would be reasonably predictable. Therefore, we chose to compare the resulting REACH HealthyTogether application to a market leader in the field, the Fitbit application.

Overall the evaluation study showed the REACH HealthyTogether application to be relevant and appropriate for older users, as participants found it to be clear, trustworthy, easy to use, relevant to their goals and more personal than the Fitbit application. End users who preferred the REACH HealthyTogether application to the Fitbit application appreciated the social connection to their physical activity buddy that the application provides through joint data representation and the adjusted messaging feature. Two participants even reported they felt that the REACH HealthyTogether application was more reliable or precise than the Fitbit application. Both the Fitbit and the REACH HealthyTogether application used the same wearable activity sensor as the source for the data they present. Thus, this perception of increased trust in the REACH HealthyTogether application indicates a higher confidence in the application possibly because it was collaboratively redesigned to specifically address their user group.

There was some indication that certain features in the Fitbit application were overlooked by older users, though these same features were appreciated in the REACH HealthyTogether application, so that we must conclude that these features were seen as relevant to the user. This apparent inability to utilize certain relevant features of a commercially available application is indicative of the challenges older users face towards interacting with these mobile technologies. Thus, although available mobile applications have potential; older users are excluded from their use due to barriers which are not addressed by prevailing accessibility guidelines in a satisfactory way.

The results of the evaluation study suggest that people with higher technology acceptance might prefer the Fitbit application to the REACH HealthyTogether application, because it is able to track a higher variety of activities. Though we did our best to recruit members of the local senior community center with varying levels of technology acceptance, there might still be a bias towards relatively high technology acceptance among our evaluation study participants. Such biases are difficult to design out of a study due to the barriers older adults face to research engagement towards development of new technologies (Eisma et al. 2004; Kopeć et al. 2018; C. Valk et al. 2019). It is however important to be aware of these biases because we aim to gain a better understanding of how to make mobile technologies more accessible to older adults with limited experience with mobile and wearable technologies.

Reflections on the Use of Behavior change Strategies

In this section we will first reflect on the implementation of the proposed design strategies and then elaborate on the resulting design probe. The REACH HealthyTogether application was the result of our codesign process, as shown in Figure 25 and Figure 26. The two versions of the application each implemented one of the suggested strategies from chapter four; the intervention application for the cooperation condition uses the social fitness strategy while the intervention application for the self-awareness condition of course uses the self-awareness strategy. In Table 30: Feature Analysis of resulting Application according to Proposed strategies we reflect on the features in the new application which support the behavior change strategy as proposed in chapter four. In both applications features supporting self-monitoring and personalization are clearly present; both applications visualize the user's daily physical activity in terms of steps measured and both applications personalize the daily step goal according to the user's usual amount of physical activity. In chapter four, example projects that used the social fitness strategy also used tunneling to guide users through the process of change. The cooperation condition here did not end up having any features which guide the users beyond the representation of their step information. However, this version of the resulting mobile application did allow a collaborative user pair to use the chat function and sticker buttons to communicate with each other through the application. In chapter four examples describing the self-awareness strategy often incorporated suggestions for users toward a certain activity but no suggestions were incorporated in this simple

research probe. In addition, an example of the self-awareness strategy tended to incorporate principles of system credibility support such as *expertise* and *real-world feel,* but it is difficult to say if these were present here. The system was introduced by the researchers from the local university which could give it some credibility. However, it is likely that these principles of credibility support were not more evident in the self-awareness version as compared to the cooperation version of the probe, so should not be attributed especially to the self-awareness version of the probe. All in all, though these research probes are simple, they do seem to embody the proposed behavior change strategies.

TABLE 30: FEATURE ANALYSIS OF RESULTING APPLICATION ACCORDING TO PROPOSED STRATEGIES

PROPOSED BEHAVIOR CHANGE STRATEGIES FROM CHAPTER FOUR	PERSUASIVE CATEGORIES*	SUGGESTIONS FOR OPERATIONALIZATION*	FEATURED OF RESULTING APPLICATION
SOCIAL FITNESS	Primary task support	Self-monitoring	Visual representation of combined daily step count as monitored by wearable tracker
		Tunneling	X
		Personalization	The daily step goal personalized to the combined step goals pairs of users worked towards
	Social support	Social facilitation	Pairs of users can use the chat function to engage in communication in addition to seeing each other's contribution to the combined daily step goal
SELF-AWARENESS	Primary task support	Self-monitoring	Visual representation of daily monitored step count
		Personalization	The daily step goal personalized to the individual
	Dialogues support	Suggestions	X
	System Credibility Support	Expertise	Potentially
		Real-world feel	Potentially

* Persuasive categories and principles from Oinas-kukkonen and Harjumaa 2009

As design research probes both versions of the application are fairly 'bare bones' and though self-awareness seems reasonably descriptive for the first version of the application, we feel 'social fitness' seems like a misnomer as it seems to imply too much from such a simple design probe application. The cooperation version of the REACH HealthyTogether application does no more than the self-awareness application except make user pairs awareness of their combined progress towards a daily step goal and implement some opportunities for communication through the application. Therefore, we feel 'social awareness' is a better name for this adaptation of the behavior change strategy earlier referred to as 'social fitness'.

Reflections On The Resulting Design Probe

A redesign process allowed us to reflect on the differences between the original application and the resulting redesigned application to examine the changes necessary to make this application more inclusive for older adults. Due to the valuable contributions of the older adult participants in our collaborative redesign process, the resulting REACH HealthyTogether application, Figure 25 and Figure 26, is very different from the original application, Figure 21. Many of the more apparent changes have to do with text size, font type, and foreground /background contrast adjustments. Beyond addressing visibility issues, the navigation and application interaction was also considered. Simplifying the application's interaction, by eliminating all the extraneous features, such as badges and counting number of flights of stairs climbed, likely contributed to the participants later describing it as clear and easy to use. Older adult collaborators in our codesign process sometimes preferred swiping to tapping virtual buttons on a touchscreen to navigate through the application. Where touchscreen buttons are used, the clickable surface area was increased substantially to allow a larger margin of error. This was important because decreased dexterity is a challenge many older adults face when interacting with mobile technologies. To address dexterity challenges further the REACH HealthyTogether application allows older users to select and send prewritten messages to their activity buddy if they do not want to type out a message. Some ideas, such as the option to use prewritten messages, in addition to the usual 'type your own' messaging feature, were a direct result of the codesign process, while other ideas were inspired by the discussions and observations from the codesign sessions, but all of these shaped the REACH HealthyTogether application.

Older adults represent a highly diverse population, so designing technologies for these users requires care and attention. The codesign process was valuable here because even after making changes in the first iteration, so that the mobile application would adhere to accessibility standards, older adult participants of our codesign session explained that they still had trouble seeing the text and suggested a different font with more line weight. Beyond visibility limitations older adults were able to share their preferences and interests in this codesign process, ultimately resulting in an application which better addresses what the users find to be valuable and relevant information, such as progress towards their personal daily goal and development over time. The codesign process informed not only how to implement certain features but which features would be most valuable to this end user group.

In this chapter we aim to describe how we used the codesign methods suggested in chapter six (C. Valk et al. 2018), to create a design probe for research into behavior change strategies in older adults. In general, from our evaluation study, it can be concluded that our collaborative redesign process was successful in creating a mobile application not only usable but relevant to older adults. Though, from the pilot study and evaluation, the resulting redesigned application does seem usable to older adults and will therefore suffice as the research probe we intended it to be, it is still unclear to what extent it addresses the user's values and needs beyond their limitations. Likely this is not a limitation of the codesign process, the benefits of which are clear (Davidson and Jensen 2013; Demirbilek and Demirkan 2004; Iversen et al. 2017; Lindsay et al. 2012), but of the highly specific design goals the researchers had. In this codesign approach researchers had a very clear idea here about the research aim of the larger study for which we needed the design probe. This redesign process might have inherently limited the creativity and freedom which the older adult participants experienced in this process. Our process here seems to have been successful in addressing limitations and barriers towards technology acceptance. However, to facilitate technology adoption, beyond acceptance, in the natural context of living, technological products should address user's values and interests not just limitations. In future processes to design 'not design probes' but technology-based health supporting products for older adults we advise researchers to be more openminded about the direction of the design process. Though our redesigned design probe likely falls short of facilitating technology adoption, we feel confident that the codesign methods, suggested in the previous chapter (C. Valk et al. 2018), were useful to overcome barriers to technology acceptance in order to create a design probe for use in a later study with older adults on behavior change strategies.

Conclusion

We have described a collaborative redesign process and shown that our codesign approach was successful in yielding a design probe in the form of a mobile application which overcame the barriers to usability that older adults, with limited technology experience, often face. We believe codesign can support the design of more inclusive mobile applications so that a wider audience can benefit from these technologies. Assessing the behavior change ability of this application was outside the scope of this investigation, but the general evaluation study of the resulting application showed it was useable and relevant to older users. This codesign process, suggested in the last chapter (Valk et al. 2018) provided researchers with a better understanding of the accessibility and usability needs that should be addressed when creating technological research probes. What is more, we gained a better understanding of how mobile technologies can be designed to be more relevant to older adults by ensuring older adult users have a voice in the design/decision process during the development of these technologies. The resulting design probe will be used in consequent field research in part 3 of this thesis.

Part Four

EVALUATION

Our design phase yielded a design probe in the form of a mobile application which employed certain behavior change strategies indicated by previous research, as described in chapter seven, thesis Part 2. In this the evaluation phase of our design research process we will evaluate our findings and conclusions related to both our main research questions:

RQ1: How can we effectively personalize behavior change solutions for older adults to motivate increased physical activity towards a healthier lifestyle?

RQ2: How can we overcome the barriers to engage older adults in research related to technology development?

First in chapter eight, we will see how a product service system approach can support older adults to engage in in-context research towards the development of technologies aimed at motivating increased physical activities. Then in chapter nine, we will examine which personal traits should be used as factors to personalize behavior change solutions by indicating which behavior change strategy to implement.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CHAPTER EIGHT

Engaging Older Adults with Technology for Behavior Change

Physical activity has been shown to increase the independence and wellbeing of older adults, yet an important segment of this community is often excluded from the necessary in-context research due to the barriers they face to technology acceptance. Currently, there is limited knowledge on how to overcome these barriers to participation. We created a specific product service system that supports older adults to engage with the proposed technological interventions to enable important in-context behavior change research. Our approach converges knowledge from the domains of living laboratories, codesign, and existing experience of design research with older adults. From our experiences with this Product Service System, we provide guidelines to support other researchers setting-up a living laboratory study with older adults to explore technology's potential to motivate behavior change.

This chapter is based off of work presented in

Valk, C. A. L., Lovei, P., Chuang , Y., Lu, Y., Pu, P., & Visser, T. (2019). Engaging senior adults with technology for behavior change. 57-68. Paper presented at Academy for Design Innovation Management, London, United Kingdom.

Introduction

The benefits of physical activity are well recognized. According to Bauman et al. (2016), physical activity can not only reduce the risk of chronic disease among older adults but also reverse symptoms of frailty, by, e.g., making physical activity instrumental to fall prevention (Bangsbo et al. 2019; Bauman et al. 2016; Chodzko-Zajko et al. 2009; Lopez et al. 2018). Most importantly, physical activity supports older adult's independence and overall quality of life.

The domain of behavior change focuses on understanding and facilitating the process of changing habits; from current behavior patterns to the adoption of new target behaviors. Personalized behavior change strategies can be implemented to spark, facilitate or support the process of adopting new habits. Technologies, such as wearable activity trackers and smartphones, have the potential to offer personalized behavior change solutions to motivate sedentary people to live more actively (Al Ayubi et al. 2014; Mitzner et al. 2010; Valenzuela et al. 2018). Research into behavior change strategies can support a better understanding of how we can take advantage of these new technologies to motivate older adults who could benefit from increased physical activity to adopt a more active lifestyle. However, behavior change is a dynamic process which is susceptible to changes in time and place or context and thus challenging to investigate without an appropriate approach. Living Laboratories (labs) are valuable methods for in-context research and vital to investigate behavior change strategies (Eriksson et al. 2005; Wu and Munteanu 2018).

Though it is clear that older adults have much to gain from the development of technologies which motivate behavior change towards a more active lifestyle, there is an important sub-group of older adults who are barred from participating in the necessary in-context research due to their relatively low level of technology acceptance (Anderson et al. 2017; EuroStat 2019). It is important to enable this group of people to participate in the development of personalized behavior change solutions not only because they offer a unique perspective but also because excluding them from development of these solutions will likely also exclude them from the benefit of these solutions and missing out on the support they need to attain more active, healthy, independent and happy lives. Therefore, researchers should be aware of specific considerations to involve older adults in the living lab research process (Eisma et al. 2004), necessary to investigate how to use behavior change strategies to support active living.

In this chapter, we report on our study design, setup and execution in order to share how we were able to address barriers to technology acceptance and facilitate an inclusive study to compare behavior change strategies. To this end, we will present some guidelines to set up a platform to design behavior change studies for older adults in a living lab context. With knowledge gathered on this topic from various areas of literature, we tailored an existing Product Service System (PSS) to enable behavior change research in a living lab context with older adult participants. This PSS was implemented to do a research study comparing motivational strategies. A reflection on our implementation of this PSS suggested that a PSS approach to a living lab research study design has potential to overcome the barriers preventing older adults from participating in such research. The purpose of this paper is to share our reflections on our process to provide inspiration to other practitioners who aim to conduct related studies.

Related Work

To best position our contribution in this chapter, we will discuss in more detail certain areas of related work pertaining to the advantages of using a living lab research method for behavior change research, technology acceptance as a barrier many older adults face to participate in these living lab studies and a review of the guidelines other authors suggest to address for this topic.

Research Towards the Development of Behavior Change Solutions

Behavior change is a dynamic process describing the adoption of new habits and routines sometimes in the place of old ones. Due to the dynamic nature of this process it is important to conduct research about behavior change in the context of use of the intervention. Often the behaviors in question cannot be simulated in a lab environment and nor could the complex web of naturally occurring facilitators and barriers to adoption of the new behaviors. Thus, in-context behavior change research into how to motivate older adults to live healthy and active lives has become increasingly important, however there are few examples of this kind. Authors Wu Munteanu, 2018, write about a study they did in which they co-created and then field tested a fall risk assessment belt with older adults (Wu and Munteanu 2018). However,

they report that their five study participants were chosen on convenience and likely do not represent a good cross-section of the very diverse older adult population as all of them had either high or medium familiarity with mobile devices (Wu and Munteanu 2018). The use of a living lab in behavior change research is accepted as a valuable method for the necessary in-context research. The advantage to living lab investigations is that living labs can offer a more realistic view of how an intervention will be used (and possibly misused) in the user's regular day to day context (Hopfgartner et al. 2014). In "Benchmarking News Recommendations in a Living Lab" author Hopfgartner et al. found living lab studies and studies conducted in a laboratory setting had different outcomes. This paper supports the view that living labs can offer a more realistic view of how an intervention will be used in the user's regular day-to-day context. Hopfgartner speaks to the "various issues" that need to be addressed in order to do living lab research (Hopfgartner et al. 2014). The limited examples of studies which do follow up codesign of new technologies with implementation and field testing, might not address but rather avoid barriers like lack of technology acceptance among older adult participants.

Barriers to Research Engagement

Despite the clear potential technology offers, there are still barriers to technology acceptance to address. The older adult population is comprised of highly diverse individuals, but there are some important factors that present barriers to a subgroup of older adults preventing them from engaging in design research, which should not go unnoticed nor unaddressed. In particular, the barriers to technology acceptance many older adults experience, present barriers to research engagement (Chen and Chan 2011; Mitzner et al. 2010; Valenzuela et al. 2018). Many new technologies do not adequately consider the mental and physical challenges some older adults may face when using this technology, such as decreased dexterity or lack of procedural knowledge (Holzinger et al. 2007; Vollmer Dahlke and Ory 2016). It can be challenging to engage older adults who have limited experience with digital devices to join research studies centered around exploring technology's potential (Eisma et al. 2004; Kopeć et al. 2018). Though codesigning technological interventions, and in-context testing, can support technology acceptance among older adults, barriers exist preventing researchers from taking advantage of these valuable research methods (Binda et al. 2018; Eisma et al. 2004; Harrington et al. 2018; Holroyd-Leduc et al. 2016).

It is clear that mobile technology's propensity to support behavior change toward increased physical activity is worth investigating. Moreover, in order to take full advantage of this potential more research needs to be conducted into how we can develop technology solutions, which address the older adult end user in valuable ways. It is therefore vital to overcome barriers to technology acceptance in order to make research practices more inclusive, because exclusion from the development of these technological behavior change solutions results in the exclusion from important health benefits. The challenge which needs to be addressed is; how can we enable older adults with low technology acceptance to engage in research towards technologies potential to support behavior change?

Review of Existing Guidelines

Experienced authors have already contributed to the body of knowledge of how to set up design research with older adults. Holroyd-Leduc, et al. reported on six points to consider when designing a research study to include older adults with frailty (Holroyd-Leduc et al. 2016) while Eisma et al. 2004, provided a more extensive list of recommendations including advice on different methods to obtain information (Eisma et al. 2004; Kopeć et al. 2018). Though it was not our purpose to conduct a literary review, below we share guidelines from some other authors who's work, and recommendations inspired our research setup for this investigation.

List of guidelines, which inspired our approach:

- Researchers should be in practical arrangements, adaptable during workshops in accordance with user needs and open to new ways to perceive, define and think about aging (Binda et al. 2018; Holroyd-Leduc et al. 2016; Malmborg et al. 2015)
- Researcher should consider the participants specific needs including, but not limited to, impaired visibility (Binda et al. 2018; Holroyd-Leduc et al. 2016)
- Take the time to facilitate use of technology in-context, to understand and respect every day practices, which ad hoc infrastructures constitute a community and what tools can be used in the codesign sessions (Harrington et al. 2018; Malmborg et al. 2015)
- Consider education or training of care providers and researchers on engagement practices (Holroyd-Leduc et al. 2016)
- Leverage experience with technology even if gained prior to study (Harrington et al. 2018)
- There may be a need to incentivize participation (Holroyd-Leduc et al. 2016)
- Actively engage the older adult participants by breaking the ice, playing games, doing workshops, and find ways to facilitate participants to actively engage with each other (Binda et al. 2018; Harrington et al. 2018)

This body of knowledge describes how to interact with participants and stakeholders during the test yet provides little clarity on how to design the setup of in-context study of technology intervention toward behavior change.

In this chapter, we describe how we facilitated in-context research to enable older adults with limited technology acceptance overcome barriers to research participation. The purpose of sharing our experiences is to enter the conversation on how to design meaningful products and services which motivate the increased physical activity, with and for older adults.

Initial Study Setup: In-Context Research to Compare behavior change Strategies

In the REACH Horizon 2020 project case, we aimed to conduct a randomized controlled trial to evaluate the effects of two different persuasive strategies on behavior change through a mobile application with older adults. For this investigation we planned to use two very similar mobile applications one of which would use the behavior change strategy self-reflection and the other application would use social reflection. This research was bookended by three workshops in which we asked participants to fill in a questionnaire. During our first onboarding workshop we introduced our participants to the research issued smartphone and activity tracker. As seen in Figure 27, we allowed for a four-week baseline to allow participants to get used to the activity tracker and the smartphone. In workshop two we introduced the intervention applications to each intervention group. After workshop two participants were asked to use the mobile application throughout a period of 5 weeks in their natural home context. In the third and final workshop we debriefed with the participants and collected the phones and trackers. In total, 65 older adult participants were recruited via a local senior community center and onboarded in workshop one (Figure 27). Of the 58 participants who finished the entire trial period, 43 were female and 15 were male and together their average age was 72.47 and the median age was 73.

Setting up valuable research of this kind requires overcoming barriers to technology acceptance so that the interventions in question are acceptable for use to the participants, and collaboration between the stakeholders involved in this context. We aimed to design a study to engage older adults with limited technology acceptance with in-context behavior change research. First, we needed to develop the two intervention applications in such a way that these were appropriate and usable for participants with limited expertise with technology, see chapter seven for more details. Next, we needed to find ways to deliver on-going facilitation to support the in-context use of the intervention applications over the course of study duration.

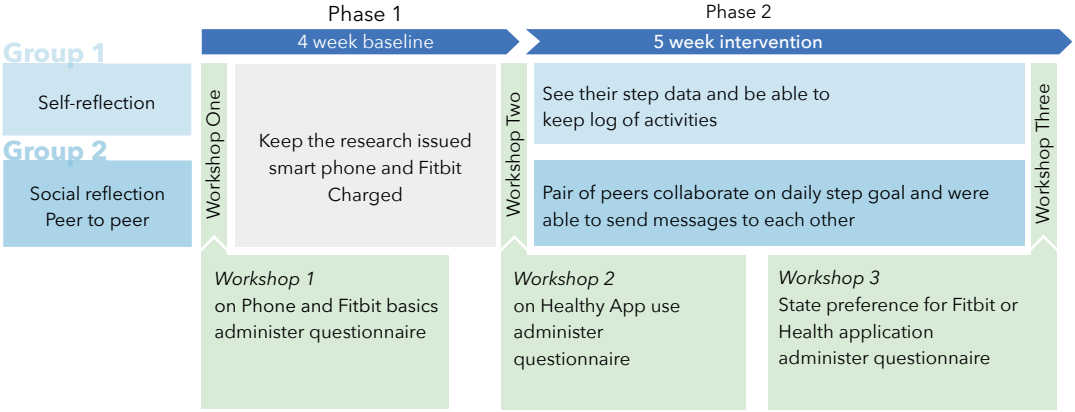


Figure 27: Simple outline of in-context research to compare behavior change strategies study

Results

The resulting study design aimed to engage older adults with limited technology acceptance with in-context behavior change research. We aimed to overcame barriers Figure 27: Simple outline of in-context research to compare behavior change strategies study with a panel of older adult participants. In order to compare the intervention application in-context we set up a living lab with a local senior community activity center. To deliver on-going facilitation throughout the duration of the study it was necessary for us to take a Product Service System (PSS) approach to the set up and execution of this research study. We used Lee and Kim's modified service blueprint to consider the following important aspects of our PSS approach (Lee and Kim 2010):

- Product and service elements layer refers to the elements that participants interacted with during the entire research study period.
- Service receiver study participant layer refers to activities that the participants undertook during the entire research study period.
- Function interactions layer refers to the activities that the design researchers conducted to create the activities of the participants.
- Onstage service provider activities layer refers to the activities that the living lab volunteers performed to support the on-going research study such as recruiting participating and technological support.
- Backstage service provider activity layer refers to the activities performed by design researchers in supporting the execution of the research study.
- Support processes layer refer to the data storage and management process in the background to support the execution of the research study.

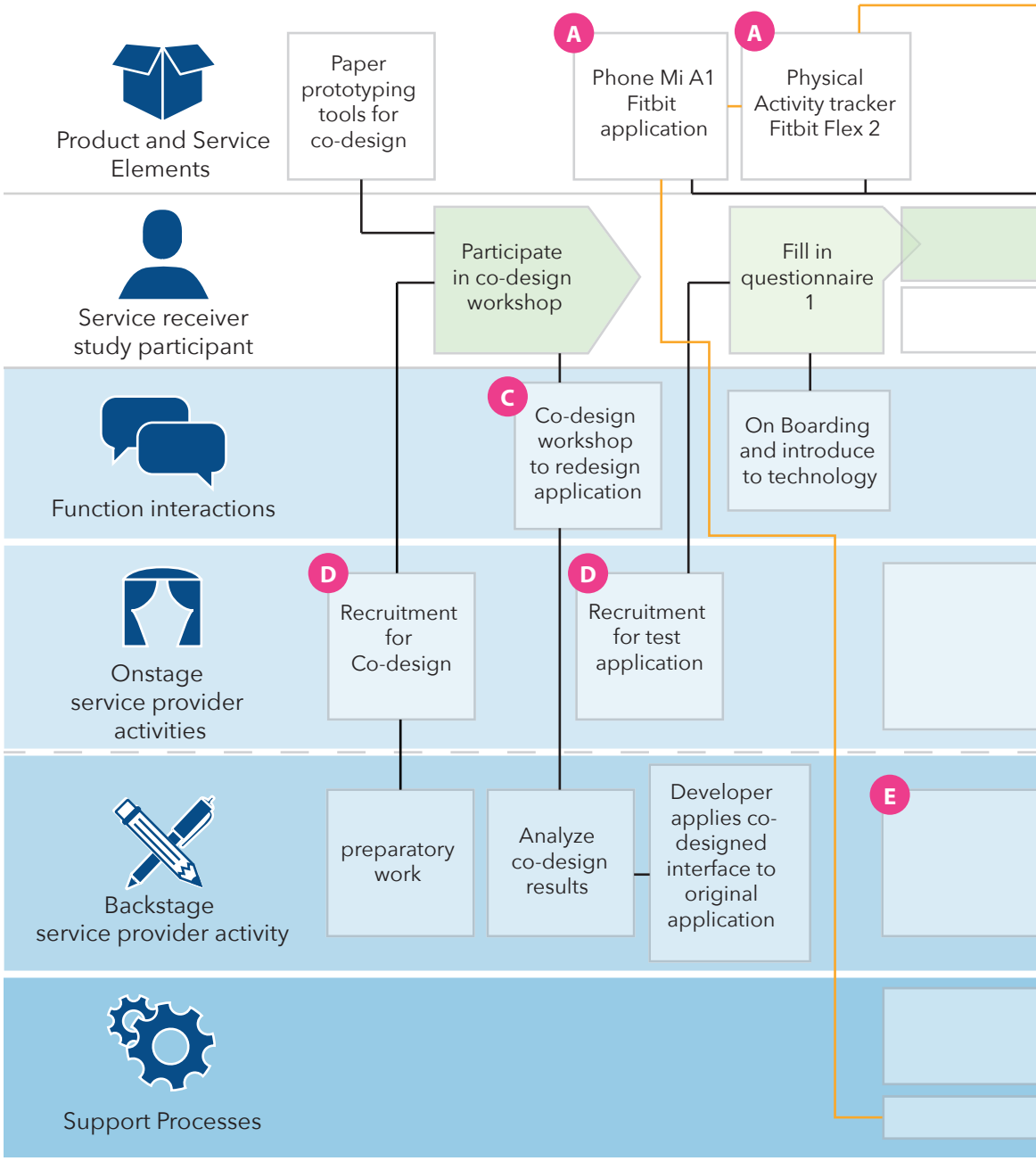
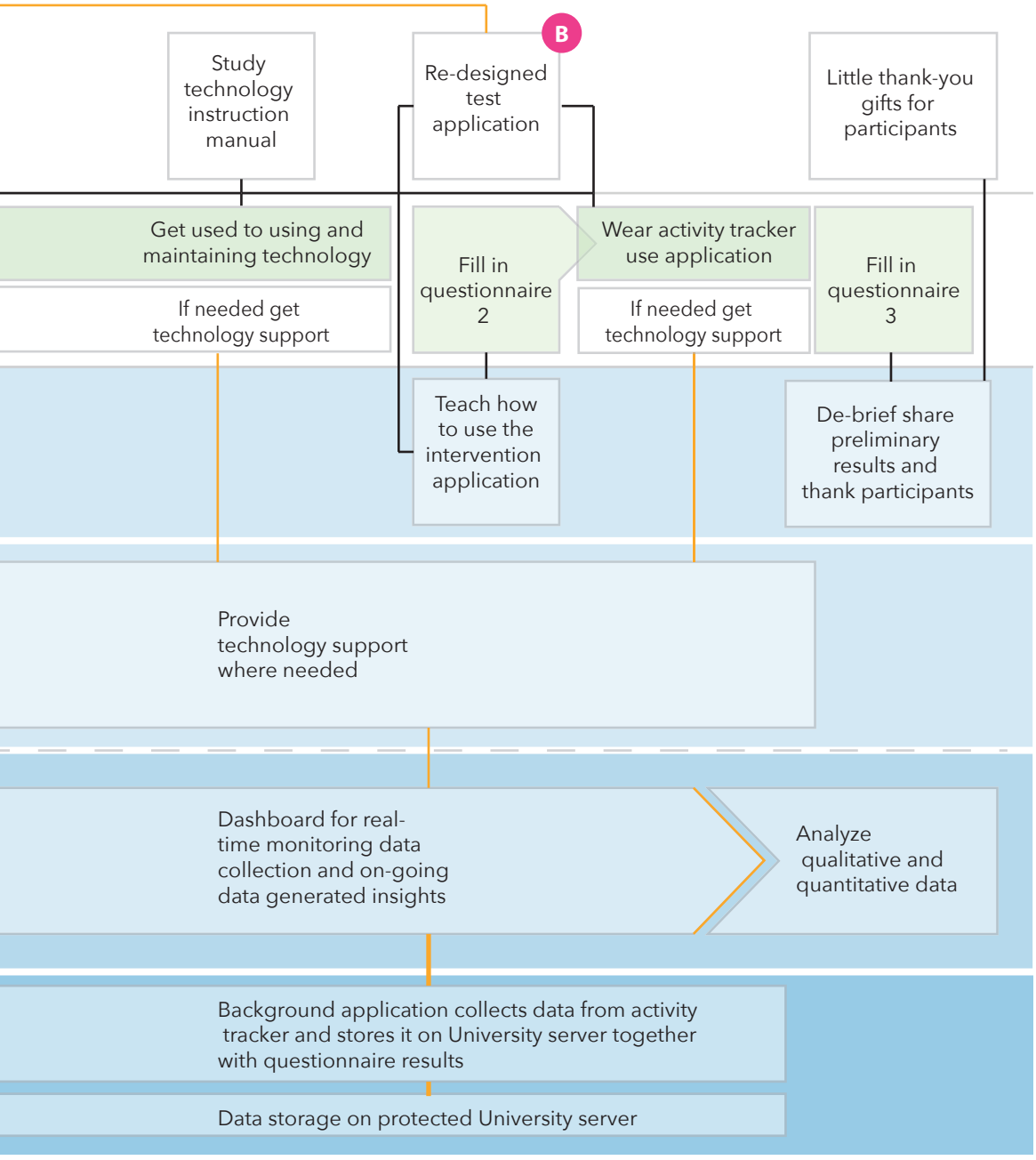


Figure 28: The product service system blueprint enabling living lab investigations to test behavior change strategies.

Figure 28 shows how the resulted product service system platform for design research study. Below, detailed results per layer will be discussed.



Functions Interactions Layer

In this study, the function interactions can be seen as the main activities of the researchers in creating activities for the participants. It consists of four main activities: Codesign, on boarding, teach how to use the intervention applications and de-briefing. These activities are explained in detail below.

Codesign

Before the intervention application could be introduced to all the study participants, researchers collaborated with a focus group of five older adults with various degrees of experience with technology to redesign a test application through codesign process, refer to Figure 28, C. It has been shown that codesigning mobile application with older adults has the potential to yield ideas that are creative and perceived as useful (Davidson and Jensen 2013). In addition, from the last chapter it was shown that end-user participating in the design process can contribute to technology acceptance (C. Valk et al. 2018). This process provided researchers with a better understanding of the accessibility and usability of the technological probes used in this study and to ensure participants had a voice in the design/decision process for this research study. Figure 29 shows some results of the codesign session, described in more detail in chapter seven. This codesign study resulted in the design of the intervention applications used in this investigation, shown in Figure 30, described in more detail in chapter seven.

Onboarding and Introduction to Technology

For this living lab study, in addition to regular onboarding, participants were given a workshop to introduce them to all of the technological elements used in this investigation. In this first workshop, researchers guided participants through all the necessary interaction steps of the study's baseline period using the study's custom manual. This thorough introduction was important to make the research inclusive for those with no or very limited prior knowledge on smartphone technology.

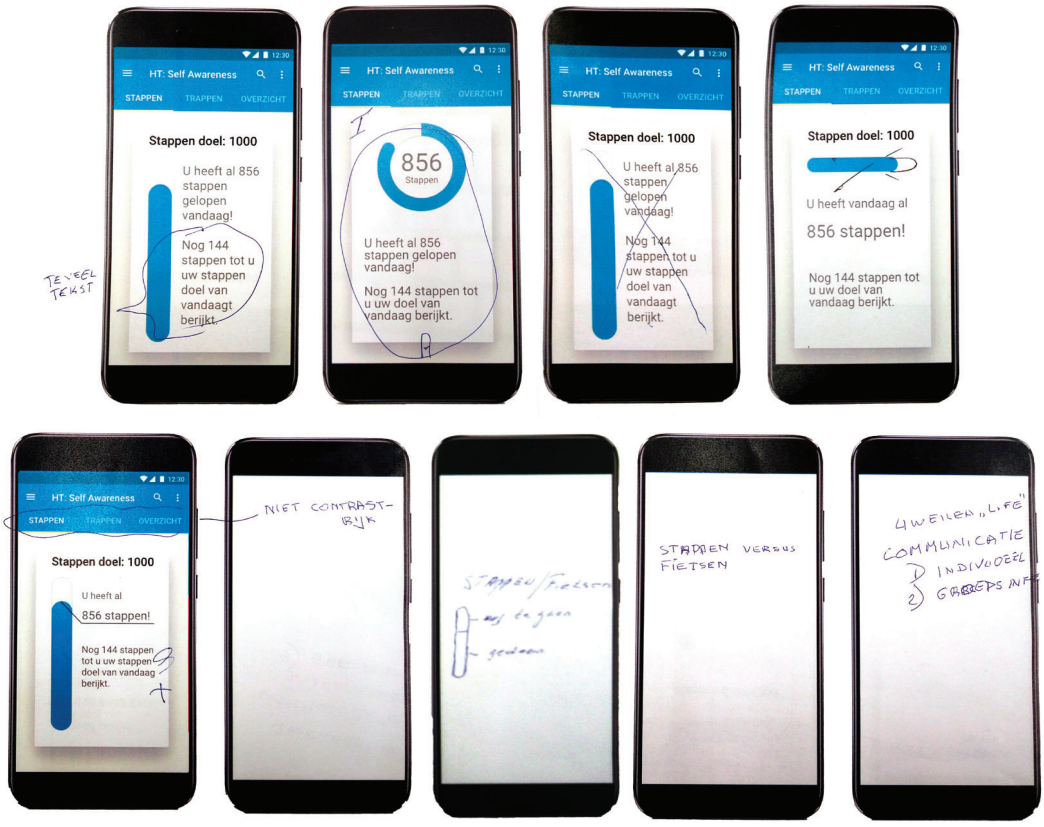


Figure 29: Some results from the application redesign session (see details in chapter seven)

Figure 30: Resulting intervention application for investigation (see more details in chapter seven)

Teaching about Application Use

To prevent overwhelming participants who might have limited experience with digital and wearable technology, participants were introduced to the intervention application after the baseline period of the test was done. During this informative session participants received the second chapter of the study specific visual manual and walked through all the functions of the application.

De-Brief

During the De-brief session, participants were surprised with a little token of thanks, and a sneak-peek into preliminary findings made possible by the real time monitoring of the research dashboard. While this session allowed participants to provide useful feedback to researchers which will improve future studies. Most importantly, it was a moment for our research team to express our gratitude to participants and reiterate the importance of their contribution.

Service Receiver Activity Layer

In this PSS the service receivers were the older adult participants of this living lab research study. Older adult participants were all community dwelling members of a local senior community center. It was advertised that prior experience with a smartphone was not a pre-requisite to participation, in order to recruit participants with various levels of technology acceptance.

Product and Service Elements Layer

We used several different product and service elements to support the functions of this PSS, such as paper products and hardware elements.

Paper Products

Paper prototyping tools were used during the codesign workshop, to prevent any barriers participating end-users may face using digital prototyping tools from hampering their input. In addition, a detailed visual manual was created, and provided in print, specifically for each condition in this study to support participants who had

limited experience with technology. This manual was provided to each participant together with a letter detailing actions required during this study. The letter was included because we acknowledge that many participants might want to talk about their participation with friends and family, and this might facilitate these conversations.

Hardware Elements

The product and service elements we used for this research study included an off-the-shelf phone, Mi A1, an off-the-shelf wearable activity tracker, Fitbit Flex2, and we tailored an existing probe to test motivational strategies, see Figure 28, A. The existing probe was a mobile application initially designed to test motivational strategies by researchers from École Polytechnique Fédérale de Lausanne (Chen and Pu 2014), Figure 28, B. We redesigned this mobile application, through a codesign session with older adults, Figure 28, C. While developers implemented changes suggested by the analysis of the results of the codesign redesign session, other members of the research team created detailed visual manuals for the phone and wearable tracker, inspired by the codesign session.

Onstage Service Provider Activity Layer

Existing close positive relationships with a senior community center also partnering in the REACH consortium allowed us to delegate most of the recruitment for the larger study, though researchers did provide flyers clearly explaining the goal of the research, and the expected commitment for participation, Figure 28, D.

During the participant onboarding process, the research team created an open and inviting atmosphere. They explained the study protocol, aim and various privacy security measures that were taken. Researchers often reminded participants of why their contributions are so valuable and worked to show participants their appreciation, by thanking them for their feedback at the end of every session, sharing preliminary insights during a debrief meeting and giving them a small gift as a token of appreciation at the end of the study. We feel the open atmosphere is key to allowing participants to feel comfortable enough to openly share their feedback with us.

Backstage Service Provider Activity Layer

Before testing, researchers redesigned and then prototyped an intervention application for testing behavior change strategies (the REACH HealthyTogether application) to make this application useable for older adult users through a codesign process (described at length in chapter seven and eight). Researchers used a custom developed research dashboard to gain real-time insight into incoming participant data, Figure 28, E. Time was set aside by members of the research team to check the incoming data and reach out to participants who seemed not to be transmitting data regularly. In addition, there was an on-call researcher who participants could call or email if they had questions about the study or use of any of the technologies provided by the research team. If, during these monitoring sessions, we noticed that there was little or no data coming in from a particular participant that participant would be contacted by phone. Usually, any problems could be solved by trouble shooting over the phone but sometimes an in-person meeting was planned to assist participants. This real-time monitoring was instrumental in preventing data loss as many participants needed to be called and helped with relatively simple things such as re-opening the background applications which facilitates the physical activity data collection.

Support Processes Layer

A background application collected data from the wearable activity tracker in real-time and stored it on a secure server at the Eindhoven University of Technology. Other data from questionnaires provided to the participants was also kept on this secure server, allowing the research dashboard to generate visualizations by drawing information from both data sets. We can recommend the use of software which allows researchers to integrate data of different kinds, such as open access weather information, questionnaire data, measured activity data etc. This insight into on-going data collection can be especially valuable to gain insight into the dynamic process of behavior change in a living lab.

Analysis

From the use of the PSS described above we can draw some early conclusions about how taking a PSS approach to a living lab investigation increases older adult engagement in important in-context research about behavior change toward a more active lifestyle. This promising increase in engagement is evident in how this study supported technology acceptance, this study's low dropout rate and anecdotes collected by the research team.

In order to support participation, it was necessary to address the barriers to technology acceptance older adults face. In order to do so, the PSS described above, initially called for a codesign session to redesign the intervention application and provided means of on-going technology support. Throughout this investigation, participant's self-reported confidence with mobile smartphone technology improved. Of the 48 participants who responded to this item on all questionnaires, 18.6% responded that they felt "very confident" about smartphone use to the onboarding questionnaire, while by the debriefing session this percentage had risen to 30.6%.

In addition to the increase in self-reported confidence about smartphone technology use, participants showed engagement through their use of the intervention technology presented during this research. Out of the 58 people who participated in this investigation 55 used the *messaging* (in the social reflection application) or the *personal log* (in the self-reflection application) functions to send messages. Overall a total of 896 messages were sent over the 5 weeks in which the intervention applications were deployed.

Supporting technology acceptance and confidence in smart-phone-use, seemed to lead to increased engagement as we enjoyed a relatively low participant dropout rate during this 9-week study. In this study, the participant drop-out rate from onboarding till the de-brief session was 11.5%. Other sources describing physical activity promoting research studies with older adults cite drop-out rates between 6 and 36% (Schmidt et al. 2000). Though some drop out, due to unforeseen or medical circumstances, is nearly unavoidable, this relatively low participant dropout rate and the overall willingness of participants to continue to participate in the study points to a relatively high level of participant engagement.

Throughout this investigation, participants made ample use of the 'on-call' technology support our team provided. To the researchers this illustrated that participants were concerned with making sure all their devices worked. Participants who reached out for technology support wanted help so they would be able to use the intervention application again. One participant who was unable to fix their problem with guidance over the phone, immediately came over to the university for an in-person meeting, because they did not want to make an appointment and wait to meet the researchers at the senior community center. This showed great motivation to want to take part in the study. At the end of the trial some participants asked if they could download the application and if the hardware was for sale, indicating an interest for continued use. Some participants mentioned talking about their physical activity information displayed in the intervention application and on at least one occasion, participants arranged to meet each other outside of the planned workshops, specially to look at the application together. In this case one participant who was more experienced with technology, took the time to explain to another participant how the provided mobile devices worked. This anecdotal evidence combined with this study's low participant dropout rate and the indication toward increased technology acceptance, suggest that participants felt engaged in the living lab research about behavior change strategies.

Discussion and Reflections

Our living lab research study addresses all of the concerns Hopfgartner et al. mention in their "Benchmarking News Recommendations in a Living Lab", through our implementation of the PSS (Hopfgartner et al. 2014). Hopfgartner et al., support living labs as a good approach to the evaluation of a product or service, while we use the living lab as a test bed to investigate behavior change strategies and to develop technologies potential. A living lab is a valuable method however, it is not adequate to overcome the barriers to technology, nor address the needs of older adults with limited technology acceptance.

Though previous work has shown the merits of codesign, living labs, and even presented guidelines for research with older adults, rarely have these domains converged as we propose here. While Liedtke et al. advocate a living lab approach to test product services systems (Liedtke et al. 2015) we advocate a product service system approach to enable living lab research to test behavior change strategies.

Davidson and Jensen, 2013, provide an example of how we can codesign digital interfaces with older adults, yet did not report on developing the proposed ideas into working applications and then testing them in a living lab setting. In their suggestion for future work, they suggest taking the experiment further to the development of the applications (Davidson and Jensen 2013), as our PSS approach has allowed us to do here. Implementing the above-described PSS approach to the setup of living lab design research can provide the necessary support to older adult participants, by providing means of on-going engagement.

The benefit of our PSS is that it has allowed our research team to consider the user experience of being a participant in living lab research. In the past, the use of PSS have been limited to either user testing a PSS (Liedtke et al. 2015) or describing PSS development methodology for business (Moon et al. 2013). Here we advocate for the use of PSS approach to design research.

Our reflections on this work have yielded guidelines we would like to share:

1. Use a Product Service System approach to set up living lab research
2. Foster relationships to build a living lab community
3. Communicate intentions and expectations ahead of time
4. Codesign necessary interfaces and interventions
5. Show appreciation for their contribution
6. Use best practice policies to ensure privacy and data security
7. Offer tech support
8. Take your time: allow time for questions and for people to get used to the new technologies
9. Facilitate continuous data monitoring
10. Share your findings

Though the preliminary evidence presented here is not conclusive, using the product service approach to create living lab environments for in-context behavior change research shows promise to increase engagement, as indicated by the relatively low participant dropouts and potential to overcome, at least in part, barriers to technology, as demonstrated by this increase in confidence with mobile devices.

Conclusion

In this chapter, we describe the PSS we created to overcome barriers older adults face to participating in living lab research for behavior change. A PSS approach to design research allows us to build on the knowledge from many different research domains which has clear benefits for the research team and participants alike. The PSS we designed enables researchers to engage older adults in living lab research about how technology can support behavior change towards a more active lifestyle, by delivering on-going support to the participants beyond the workshop moments and throughout the several weeks of the study. In our PSS concept, detailed in Figure 28, we built on existing guidelines for engaging older adults in research. Like Harrington et al. 2018, we made sure to provide users with relatively limited experience with mobile technologies time to use and get used to the new devices (Harrington et al. 2018). We continued to build a close working relationship with the older adult organization where we conducted our living lab study, in line with the guidelines provided by Eisma et al. (2004) (Eisma et al. 2004). Marin-Hammond et al. (2018) also suggests working with relevant organizations to recruit participants (Martin-Hammond, Vemireddy, and Rao 2018). The service provider is an important partner and expert in facilitating this necessary living lab research. Therefore, we would like to encourage other design researchers to follow up the PSS idea by teaming up with expertise outside of the design field to engage and empower older adults to contribute to behavior change research in living labs.

The purpose of this paper is to share our reflections on our process to provide inspiration to other practitioners who aim to conduct related studies. With this contribution we hope to build a more inclusive research environment to include members of more difficult to access communities toward a better understanding of behavior change strategies.

CHAPTER NINE

Creating Motivational Profiles

In the last chapter, we addressed our research question concerning how to engage older adults in in-context research towards the development of technologies for behavior change. The purpose of this chapter, chapter nine, is to address our research question concerning personalized behavior change strategies in order to effectively motivate increased physical activity among older adults. Throughout this work, we describe how we facilitate in-context research to enable older adults, with limited technology acceptance, overcome barriers to research participation.

Personalizing behavior change strategies to motivate increased physical activity is especially important for the diverse older adult population. However, there is a lack of knowledge about how to profile older users to most effectively personalize behavior change solutions. Self-awareness and social awareness are behavior change strategies commonly used in commercially available applications to promote physical activities and identified as promising strategies for behavior change among older adults in chapter four (Valk et al. 2017). Through a randomized controlled trial (N=53), we studied the effect of some personal factors on the physical activity of older adults under these two strategies. For this purpose, each behavior change strategy was implemented in a mobile application. Based on the statistical analysis of the measured step data and the collected questionnaire data, we identified a list of personal factors to personalize each behavior change strategy towards improved physical activity. Hereby we suggest how to create effective motivational profiles to personalize these behavior change strategies toward increased physical activity for older users.

Figure 31: User demonstrates use of intervention application

This chapter is based on work submitted for publication in the International Journal of Design

Introduction

It is clear that there is a need to investigate how to effectively personalize behavior change solutions for older adults for the benefit of their health and wellbeing. Experts agree that to this end, profiling is a valuable method to personalize behavior change strategies (Friederichs et al. 2015; Hardcastle and Hagger 2016; Kaptein, Markopoulos, et al. 2015; LeRouge et al. 2011; Looman et al. 2018), yet there is no consensus on what personal factors should characterize or determine the user's behavior change profile. Additionally, once users have been profiled, it is not always clear how these profiles can inform design decisions such as which behavior change strategy is most appropriate for a specific profile of older users. There is a need to further investigate which factors might be indicative of a user's reaction to an applied behavior change strategy beyond only factors such as age and gender.

To address this gap, we conducted a randomized controlled trial investigating the effect of two commonly used behavior change strategies (self-awareness and social awareness), identified as promising in chapter four, on the physical activity of a group of 53 older adult participants, between a baseline and intervention measurement over the course of 9 weeks. To test these two behavior change strategies, they were each implemented into otherwise very similar mobile applications, pictured in Figure 31. In addition, we analyzed the effect of several personal factors, captured by questionnaires, on the increase in physical activity.

A series of regression analyses were run to identify which personal factors predicted an increase in physical activity for each intervention. From this analysis, we clustered the personal factors which were found to be significant, into motivational profiles, linked to the relevant behavior change strategy.

In this way we want to contribute these motivational profiles to add to the body of knowledge on personalizing behavior change strategies. We believe a better understanding of how to personalize behavior change strategies for older adults, is of vital importance to improving behavior change solutions, which motivate older adults to increase their physical activity and hereby improve their quality of life.

Related Work

In order to support increased engagement with physical activity, behavior change solutions need to be personalized to appropriately address the needs of the highly diverse older adult population. Personalization has been shown to increase the effectiveness of behavior change solutions (Bull et al. 1999; Cabrita et al. 2015; Campbell et al. 1994; Purpura et al. 2011; Schutzer and Graves 2004). Additionally, strong evidence indicates that when designing for older adult users the need for personalization is even more important (Cabrita et al. 2015; LeRouge et al. 2011). However highly personalized solutions tailored to one individual are costly to create and practically impossible to implement on a larger scale. As current automized personalization methods, such as purchase recommendary systems used in online marketing or in-app goal setting due to previous activity levels, lack the necessary contextual and psychological depth beyond measured activity data or other measured physiological data (Kaptein, Markopoulos, et al. 2015). Experienced authors advocated that user profiles have the potential to increase the effectivity of the behavior change solution by allowing for a more personal approach than the inadvisable 'one size fits all', while streamlining the creation of these behavior change interventions by avoiding bespoke interventions (Friederichs et al. 2015; Hardcastle and Hagger 2016; Kaptein, Markopoulos, et al. 2015; LeRouge et al. 2011; Looman et al. 2018).

To this effect, researchers have conducted studies to discover which personal factors should be considered when creating such a profile. Though certain constructs such as age, gender and ethnicity are very often used to construct user profiles, authors see the value in using a combination of contextual and psychological factors to profile users for interventions that support physical activity. Psychological factors such as stage of change (Prochaska and Velicer 1997), social efficacy, self-efficacy (Sherer and E.Maddux 1982) in combination with other personal factors could inform design choices towards the creation of behavior change solutions (Brug, Campbell, and Assema 1999; Lee et al. 2008; Looman et al. 2018; McAuley, Konopack, and Motl 2006). However, little is known about which specific combination of personal factors could be used to profile older adults to inform which behavior change strategy should be applied.

While some form of self-monitoring or self-awareness might be the most prevalent behavior change strategy, when considering commercially available physical activity

monitors, social interventions are also often used to motivate increased physical activity. Several mobile applications allow users to share their recorded physical activity to their social network for example. In addition, authors have explored how social connectedness even when mediated through digital and technological devices can enhance the wellbeing of older adults (Visser et al. 2011). There are of course many behavior change strategies and technics (Michie et al. 2015), but besides being commonly used to support increased physical activity (Lyons et al. 2014; Middelweerd et al. 2014), both the self-awareness (McMahon et al. 2016) and social awareness (Kononova et al. 2019) type behavior change strategies were found to have potential for older adult users (see chapter four) (Valk et al. 2017). Still, it is difficult to know which behavior change strategy is most appropriate to use to address the older adults when designing behavior change solutions.

In this study we attempt to examine the effect of the above-mentioned personal factors on the increase in physical activity of older adults using a design probe employing either the self- or social awareness behavior change strategy.

Method

As mentioned in the introduction we were interested to learn which personal profiling factors (age, gender, smartphone use confidence, stage of change, overall physical activity, self-efficacy, social efficacy) effect physical activity (in terms of relative increase in number of steps per day) and whether there are any personal factors that could indicate a significant improvement in physical activities depending on the intervention behavior change strategy applied. Thus, the purpose of the study was to find out whether age, gender, smartphone usage, stage of change, social efficacy and self-efficacy have a statistically significant effect on the relative improvement on daily physical activities under the social awareness and self-awareness strategy, respectively.

In this section we report on the study design, the participants, the intervention hardware and software, the data we collected, and the data protection practices we used.

Study Design

This study consisted of a two-group randomized controlled trial, with a four-week baseline and a five-week intervention measurement phase, see Figure 32. During the baseline phase of the study each participant was asked to wear a step counter without a display and to keep a research-issued phone charged at their home for data collection purposes. During the intervention phase of the study participants were asked to use the research-issued smartphone to view their daily steps through interacting with the intervention application they were allocated. Three workshops were organized with no more than 20 participants at a time: 1) Onboarding and introduction workshop to procedure and expectations, 2) Workshop teaching participants how to use the intervention application they had been allocated, and 3) De-briefing workshop to provide participants with preliminary insights from the study and thank them for their participation. Participants were also asked to fill in a list of questionnaires to collect more information on personal factors, potentially relevant to motivational profiling, see the details in the data collection section.

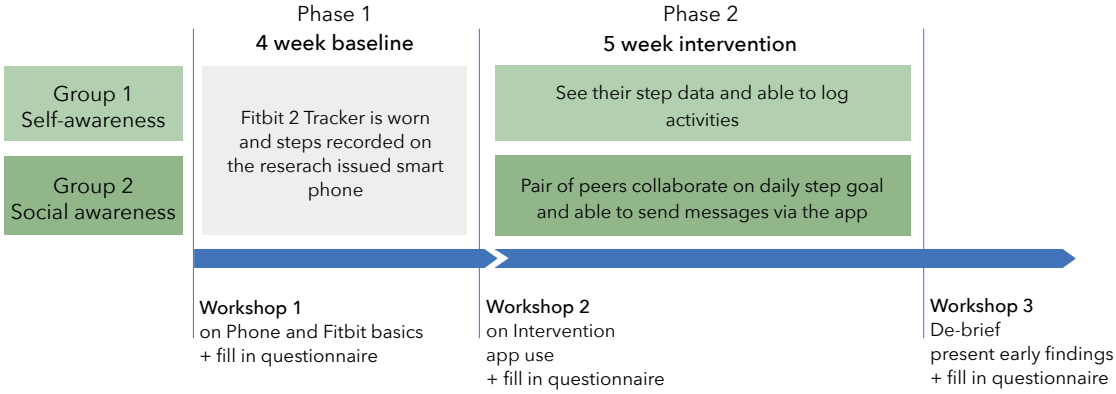


Figure 32: Basic outline of the randomized controlled trial including baseline and intervention phases and workshops

Participants

All participants of the study were recruited in close collaboration with a trusted third party, in this case the founder and volunteers from the local senior community center. Handouts describing the study and inviting members to the onboarding session were distributed among the members of the senior community center several weeks before the first onboarding workshop, giving potential participants ample time to consider

if they would like to join the study. Community dwelling older adult members of the local senior community center were the main target group of this recruitment though some volunteers of the center also decided to join the study. Older adult members of the senior community center all have a Tilburg Frailty index of larger than five (Gobbens et al. 2010), describing them as independent yet reliant on some support or care for activities of daily living, such as help with strenuous household tasks or relying on a walking aid.

Software Intervention

For this investigation, it was necessary to redesign the original HealthyTogether application (Chen and Pu 2014), into the REACH HealthyTogether application through a co-creation process with a panel of 5 older adults, representative of the larger group of study participants, described in part two of this thesis. Two very similar versions of the resulting REACH HealthyTogether application were created each implementing a behavior change strategy identified as promising for older adults in chapter four. The first version integrated the self-awareness behavior change strategy and the second integrated the social awareness behavior change strategy into the application, see Figure 33 and Figure 34 respectively. The main difference is that in the self-awareness application (Figure 33) the circle on the 'today' screen visualizes one user's progress toward a personal daily step goal while in the social awareness application Figure 34 the circle represents the total progress of the user and their buddy towards a combined daily step goal. Each combined daily step goal is the sum of the individual step goals of the user and their buddy, but no distinction is made in the progress visualization about which buddy has contributed most that day. In the 'history' overview, both applications allow users to scroll through daily step totals achieved in previous days. In this view, those using the social awareness version can gain insight into their personal number of steps compared to that of their buddy.

Figure 33: Intervention application for the self-awareness condition

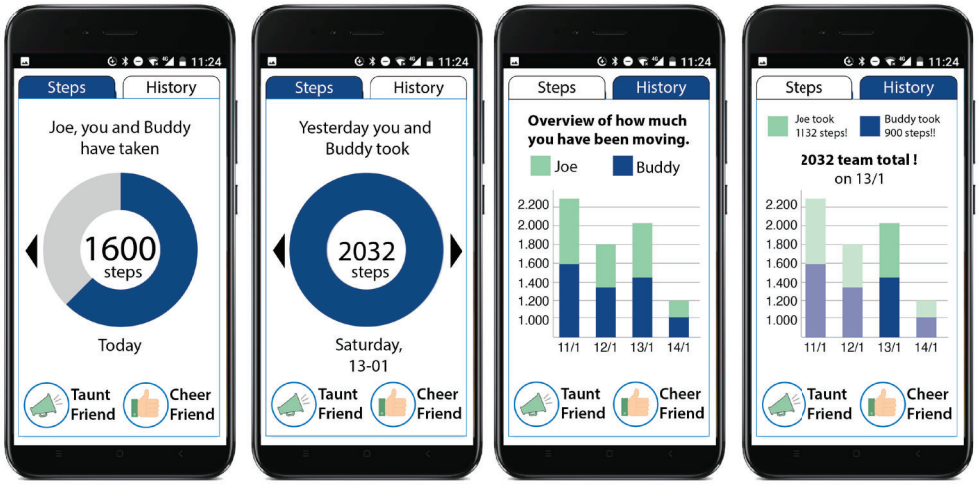


Figure 34: Intervention application for the social awareness condition

Hardware Intervention

The hardware used to support this study consisted of the Fitbit Flex2 and the Mi A1 smartphone. Both pieces of hardware were considered due to practical reasons e.g. cost, availability and approval by the aforementioned panel of participants. The Mi A1 phone was chosen due to screen size and regular security updates of the operating system. The Fitbit Flex2 was chosen due to the practicality of it being waterproof, featuring exercise detection and not having a screen to show number of steps which was important in order to run the baseline phase of the study.

DATA COLLECTION

By means of a questionnaire we collected information on participants age, gender, self-reported confidence in using a smartphone (smartphone confidence), stage of change (Prochaska and Velicer 1997), social and self-efficacy (Sherer and E.Maddux 1982), see Table 31. By means of the wearable activity sensor, the Fitbit Flex 2, we collected step data during both the baseline and intervention phases of the study.

TABLE 31: OVERVIEW OF DATA COLLECTION

PERSONAL FACTORS	*DESCRIPTION*	*MEASUREMENT*
Data collected via pre intervention phase Questionnaire		
Age	Participant's age	In years
Gender	Participant's gender	Male or Female
Stage of change	Collected using the questionnaire from the transtheoretical model of behavior change (Marcus, Bess H.|Lewis 2003)	In phases: Precontemplation, contemplation, preparation, action, maintenance
Self-efficacy	Collected using the questionnaire from the efficacy scale (Sherer and Maddux 1982)	Numerical outcome
Social efficacy	Collected using the questionnaire from the social efficacy scale (Sherer and Maddux 1982)	Numerical outcome
Data collected via post intervention phase Questionnaire		
Smartphone confidence	Self-reported confidence in using a smartphone	on a 5-point Likert scale:
Data measured with wearable activity sensor during both baseline and intervention phases of the study		
Daily step total	Measured by Fitbit Flex 2	Numerical; daily step total

Data Security and Ethics

To protect the privacy of our participants, the necessary personal information, such as contact information, was encrypted and stored offline. In addition, this sensitive information was only shared with those researchers who required it to run the study, for example to provide tech support. For much of the general communication toward the participants, researchers relied on the support of the partnering senior community center, which already possessed contact information for all their members and in doing so avoiding, in many cases, the necessity to record this personal data. This data

collection and storage was described in layman's terms during the first workshop before participants were invited to sign the informed consent as part of onboarding. A flyer describing the data collection and storage and a flyer describing the study and how to contact the research team was also handed out for participants to take home.

Responsible parties of this senior community center and knowledgeable people at the Eindhoven University of Technology approved our protocol, data collection and storage practices.

The data collected from this study was anonymized and made available to the REACH Horizon 2020 consortium in order to comply with the consortium agreement and requirements. This consortium will further communicate the already deidentified data to others following GDPR regulations and ensure the FAIR principles are being applied. To share this anonymized data end to end encryption was used.

Results

The participants were recruited by the partnering senior community center based on their willingness to participate in the study. Less than two weeks of measured step data in either the baseline or the intervention phase of the study excluded that case from any calculations concerning physical activity.

81 older adult potential participants signed up to come to the onboarding workshop and were assigned to use either a social awareness or a self-awareness intervention application prior to the onboarding workshop. At the conclusion of the study, out of the 49 participants who used the social awareness intervention 11 people dropped out of the study (22.45%) and out of the 32 participants who used the self- awareness intervention 12 participants dropped out by the end of the study (37.50%). After exclusion criteria were enforced 53 participants remained (Table 32).

TABLE 32: PARTICIPATION AFTER DROPOUT AND EXCLUSION CRITERIA WERE ENFORCED

	NUMBER OF PEOPLE ON-BOARDED	*NUMBER OF PEOPLE STILL PARTICIPATING AT THE END OF THE STUDY*	*AFTER EXCLUSION DUE TO LACK OF MEASURED STEP DATA*
Self-awareness	32	20	15
Social awareness	49	38	38
Total	81	58	53

Personal Profile Results from the Questionnaire

Out of the 53 remaining participants 40 were female and 13 were male. Participants had a mean age of 72.38, a median age of 73 and mode of 76. Of the remaining 53 participants 49 participants completed the self-efficacy questionnaire with scores ranging from 17 to 40, with a mean score of 32.47. 50 participants completed the Social efficacy questionnaire with overall scores ranging from 9 to 22 with a mean score of 17.06. Out of the 48 participants who completed the stage of change questionnaire we found most participants to be either in the action (15) or the maintenance (24) stage of change. More specific information about the study population, in terms of the examined personal factors is reported in Table 33.

TABLE 33: PARTICIPANT DETAILS

	PERSONAL FACTOR	NUMBER OF PEOPLE
Gender	Male	13
	Female	40
Age	Under 70 yrs.	15
	Between 70-79 yrs.	26
	Over 80 yrs.	12
Stage of change	Precontemplation	1
	contemplation	5
	Preparation	3
	Action	15
	Maintenance	24
Self-Efficacy*	Low	19
	Middle	10
	High	20
Social Efficacy*	Low	16
	Middle	19
	High	16
Smartphone confidence	1.I have never used a smartphone	7
	2.Very confused or frustrated	2
	3.A little apprehensive	7
	4.Somewhat confident	20
	5.Very confident	14

*both Self-efficacy and social efficacy are measured by validated questionnaires yielding a numerical outcome. However, for the ease of legibility these values were split into the lowest 33%, and highest 33% and the rest was allocated to the middle.

Measured Physical Activity Results

In addition, the daily step data collected showed diversity within this population. The lowest average number of steps measured a day during the baseline was 1556.08 while the highest average, for the same, was 18432.10. The mean difference in number of steps between the baseline and the intervention was 568.96, but due to the large differences in average number of steps it is relevant to consider not just the absolute difference but also the relative improvement for each participant, Equation 1. Table 34 provides more details on the data collected concerning physical activity in terms of number of steps a day.

$$\frac{\textit{(Average \# of steps during Intervention phase)-(Average \# of steps during Baseline phase)}}{\textit{(Average \# of steps throughout enitre study or 'overall physical activity')}}$$

Equation 1: How we calculated relative improvement for each study participant

TABLE 34: DETAILS ON PHYSICAL ACTIVITY IN NUMBER OF STEPS A DAY

	Mean	Std. Error of Mean	Median	Min	Max
Average Baseline	8265.91	528.67	7239.45	1556.08	18432.1
Average Intervention	8834.87	540.43	7886.44	2229.03	18471.69
Difference in averages	568.96	184.96	452.06	-1815.79	4884.52
Relative improvement	10.04	3.23	6.52	-19.72	127.94
Overall physical activity	8550.39	526.52	7783.60	1892.56	18452.89

Analysis

The research question we aim to address with this investigation concerns the relationship between personal profiling factors and effectivity of applied behavior change strategies, in terms of relative improvement in daily step count between the baseline and intervention phases of the study. In our analysis of the above reported results we first addressed the entire data set and then we examined each intervention condition on its own.

Analysis of the Complete Data Set

The central purpose of this analysis was to investigate which personal factors, and to what extend each of these, had an effect on the relative improvement in steps taken per day. To this end, we ran a multiple regression to predict relative improvement in steps between the baseline and the intervention phases of the study from gender, age, self-efficacy, social efficacy, stage of change, intervention application used during intervention phase of the study, overall physical activity level throughout entire study and self-reported smartphone confidence.

Our regression required some initial data processing. As an ordinal variable cannot be used in a multiple regression, we created dummy variables to change the ordinal variables (overall physical activity, smartphone confidence, and stage of change) into dichotomous variables.

An assessment of partial regression plots and the studentized residuals against the predicted values plot showed there was linearity. We found independence of residuals, as assessed by a Durbin-Watson statistic of 2.132, and homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. The studentized deleted residual all fell between -1.653 and 2.437 except out outlier with the value of 6.567 and almost all of the leverage values were above the 'problematic' value of 0.2. However, the Cook's distance values were never above 1, so we continued with this regression.

The multiple regression analysis showed that R2 for the overall model was 41.1% with an adjusted R2 of 8.4%. Age gender, intervention application allocation, self-efficacy, social efficacy, overall level of physical activity, stage of change and self-reported smartphone confidence were not statistically significant to predict relative improvement, with $F(15, 27) = 1.257$, $p = .293$. From the SPSS calculated Coefficients, reported in Table 35, we see that only app allocation, stage of change: 'action', and self-reported phone confidence; 'a little confused', are statistically significant to relative difference between steps taken during the baseline and the intervention periods of the study.

TABLE 35: SUMMARY OF MULTIPLE REGRESSION ANALYSIS, COEFFICIENTS TABLE

VARIABLE	B	SE_B	β	Sig.
INTERCEPT	-65.990	57.544		.262
GENDER	4.943	9.976	.093	.624
AGE	.081	.551	.031	.885
CONDITION ALLOCATION	25.917	9.972	.487*	.015
PRECONTEMPLATION	-36.864	33.780	-.233	.285
CONTEMPLATION	-9.417	23.374	-.127	.690
PREPARATION	6.920	18.044	.113	.704
ACTION	22.293	10.625	.467*	.045
OVERALL PHYSICAL ACTIVITY LOW	-8.364	10.273	-.167	.423
OVERALL PHYSICAL ACTIVITY MID	-1.328	9.948	-.026	.895
SMARTPHONE CONFIDENCE 1	-5.805	27.662	-.090	.835
SMARTPHONE CONFIDENCE 2	-2.592	28.186	-.042	.927
SMARTPHONE CONFIDENCE 3	26.772	12.676	.535*	.044
SMARTPHONE CONFIDENCE 4	-8.480	13.130	-.155	.524
SELF-EFFICACY	.859	1.177	.171	.472
SOCIAL EFFICACY	-.612	1.753	-.080	.730

Note. *p < .05; B = unstandardized regression coefficient; SE_B = Standard error of the coefficient; β = standardized coefficient

Analysis of the Two Intervention Conditions

To determine that there was no accidental bias in the allocation of the self-awareness and social awareness intervention groups, we examined the average number of steps taken in each group during the baseline phase of the study, before any intervention was introduced. We used a Mann-Whitney U test to investigate the average number of steps taken during the baseline, across these two intervention groups. Distributions of the average number of steps taken a day during the baseline phase of the study were similar across the two groups, despite the disparity in number of participants. From this test we found that median engagement score for Self-awareness (7706.90) and social awareness (7004.65) was not statistically significantly different, $U = 264$, $z = -.415$, $p = .678$.

Originally, we aimed to run a similar multiple regression on each intervention condition group separately. However, when divided into the two different intervention conditions, the data from the self-awareness group was not sufficient to run a multiple regression, as the data did not meet the Durbin-Watson requirement and had multicollinearity problems even after excluding some of the troublesome variables. Instead we used a nonparametric correlation analysis to find the strength and direction of the relationship between each personal factor examined and the relative increase in physical activity measured for this intervention condition. The Kendall's tau-b (τ_b) correlation was used to find the relationship between each personal factor examined and the relative improvement in steps, see details in Table 36. Age, stage of change and smartphone confidence were found to have a statistically significant effect (at 95% confidence, for age, $p = 0.017$, for stage of change $p = 0.28$, and for smartphone confidence $p = 0.032$) on the relative improvement of daily physical activities stimulated by self-awareness.

TABLE 36: RESULTS OF THE CORRELATION ANALYSIS BETWEEN PERSONAL FACTORS AND RELATIVE IMPROVEMENT OF PHYSICAL ACTIVITY OVER THE DATA OF THE SELF-AWARENESS CONDITION

Kendal's Tau-b Correlation Run on the Self-Awareness Condition

Personal factors	Self-awareness intervention condition	
	τb	Sig. (2-tailed)
Gender	.110	.624
Age	.464*	.017
Self-efficacy	-.187	.387
Social efficacy	-.013	.951
Stage of change	-.489*	.028
Smartphone confidence	-.457*	.032
Overall Physical activity	-.238	.216

Note *p < .05. Results of the correlation analysis between personal factors and relative improvement of physical activity over the data of the self-awareness condition

For the data from the social-awareness group, it was feasible to run a multiple regression analysis after the validation. Accordingly, we ran another similar multiple regression analysis on only the data set from this intervention group, detailed results listed in Table 37. Linearity and homoscedasticity were established by assessment of the relevant plots. There was an independence of residuals, as the Durbin-Watson statistic was found to be 2.166. The studentized deleted residual all ranged from -1.743 and 2.304 and all of the centered leverage values were above the 'problematic' value of 0.2. Cook's distance values were never greater than 1.R^2 for the overall model was 48.7% with an adjusted R^2 of 7.1. age, gender, self-efficacy, social efficacy, overall physical activity, and smartphone confidence were found not to be statistically significant to relative improvement in daily steps, $F(13,16) = 1.171$, $p = .377$. However, we did observe that stage of change: preparation was significant, $p = .061$ at a confidence level of 90%.

TABLE 37: SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF SOCIAL AWARENESS INTERVENTION CONDITION

VARIABLE	B	SE_B	β	Sig.
INTERCEPT	61.670	45.036		.190
GENDER	-8.786	12.443	-.214	.490
AGE	.511	.407	-.304	.227
PRECONTEMPLATION	-13.042	31.436	-.143	.684
CONTEMPLATION	-33.437	24.491	-.611	.191
PREPARATION	30.048	14.907	.733*	.061
ACTION	6.099	9.989	.182	.550
OVERALL PHYSICAL ACTIVITY LOW	-2.317	9.785	-.068	.816
OVERALL PHYSICAL ACTIVITY MID	-2.080	8.807	-.060	.816
SMARTPHONE CONFIDENCE 1	Excluded by regression because it could be perfectly predicted by the other smartphone confidences levels.			
SMARTPHONE CONFIDENCE 2	30.667	18.650	.635	.120
SMARTPHONE CONFIDENCE 3	-6.201	12.973	-.160	.639
SMARTPHONE CONFIDENCE 4	-4.227	10.419	-.114	.690
SELF-EFFICACY	-.545	1.208	-.166	.658
SOCIAL EFFICACY	.240	1.562	.048	.880

Note. *p < .10; B = unstandardized regression coefficient; SE_B = Standard error of the coefficient; β = standardized coefficient

In conclusion, from running a multiple regression on the entire data set we found application allocation (intervention condition), stage of change and smartphone confidence to have a significant relationship with relative increase in physical activity. The correlation analysis of the self-awareness intervention condition reiterated the relevance of stage of change and smartphone confidence, while also showing age to be significantly correlated to the relative improvement in total daily steps. The multiple

regression analysis of the data from the social-awareness condition suggested that stage of change at preparation was found to have a statistically significant effect to the relative improvement.

These findings suggest the self-awareness behavior change strategy might effectively address people with low smartphone confidence, at an earlier stage of change and of advanced age. While the social awareness strategy might be used to address people who are already in the preparation stage, more effectively.

In the next section we will discuss each of these personal factors in detail with some additional explorations.

Further Analysis and Discussion

The aim of this work is to investigate how to profile older users, to most effectively personalize behavior change solutions towards increased physical activity. To the end we conducted further investigations of each personal factors here examined. This investigation yielded some discussion worthy results, and some noteworthy limitations which will be discussed at length in this section.

Age

We were originally interested in age specifically because it seems to be one of the most commonly used profiling factors. Yet, from our regression analyses we found that age did not have a significant relationship with relative improvement, for the overall participant group nor for the social awareness group. However, in the smaller self-awareness group, age was found to positively correlate to the relative improvement of physical activity. To examine the relationship between physical activity and age further we conducted a Spearman's rank-order correlation to examine the relationship between age and overall physical activity. From this correlation we found that there was a statistically significant, moderate negative correlation between age and overall level of physical activity, $r_s(95) = -.304$, $p = .027$. This finding resonated with other sources which site similar findings: as age increases, physical activity tends to decrease (Davis et al. 2011).

There is a general misconception that the potential for change decreases with age, so bluntly but aptly described in the age-old adage; "you can't teach an old dog new tricks". However, our findings suggest that age affects absolute physical activity but not the individual relative improvement stimulated by the two tested behavior change strategies. If we examine relative improvement, as a manifestation of potential to change physical activity habits, we find that there is no decrease in potential towards this kind of change with age. This finding reaffirms the importance of personalized behavior change research and its potential to benefit older adults.

Gender

Gender is commonly used as a personal factor for profiling however from our regression, and subsequent analysis, we found gender not to be correlated with relative improvement. To examine the relationship between gender and overall physical activity in steps we ran a Kendall's tau-b correlation. There was a very small negative association between gender and overall physical activity, and this too was not statistically significant, $\tau b = -.043$, $p = .710$.

This outcome might be the result of the disproportionate number of men and women we were able to recruit. On the other hand, these results might suggest that, among this population, gender was less important as a personal factor informing the effect of behavior change stimuli. Due to the disparity in numbers between men and women, these results are not conclusive. More specific research into this factor should be conducted to gain a more comprehensive understanding of whether gender should or should not be considered an important factor to inform the choice of behavior change profile.

Self-efficacy

In addition to the regression reported in the results section of this paper, we also conducted a separate Spearman's correlation to see if we could find a relationship between the participant's self-efficacy and their overall physical activity measured. 49 participants completed the self-efficacy questionnaire and were included in this analysis. As in the regression analysis we found no statistically significant correlation between self-efficacy and overall physical activity, $r_s(49) = .028$, $p = .849$.

In other studies authors cite the importance of self-efficacy to behavior change (Marcus, Bess H.|Lewis 2003), however our findings here do not support this directly. This might be because the self-efficacy questionnaire is not validated for this group of the population. Researchers did get comments from several participants that the questionnaire was long and some of the questions confusing. In comparison to the 4-question stage of change questionnaire the 16 questions of the combined self- and social efficacy questionnaire might have been fatiguing for some participants in such a way that the tool did not measure this construct accurately. In addition, there might be some physical limitations to the activity that certain participants were able to achieve, due to a dependence on walking aids for example, despite their self-efficacy. To investigate this construct further, we would need a more specific research study geared to looking specifically at the effect of self-efficacy on relative improvement to of physical activity.

Social Efficacy

As with self-efficacy, to determine whether social efficacy score was correlated to the relative difference in averages we ran a Spearman's rank-order correlation. 50 participants completed the social efficacy questionnaire. A visual inspection of the scatterplot indicated the relationship to be monotonic. Results of this investigation show that there was no statistically significant correlation between social efficacy score and relative difference in averages, $r_s(50) = -.030$, $p = .835$. These results could be attributed to the fact that we did not measure social activity specifically in this study. Potentially, participants with a higher social efficacy did become more socially active, like going to the senior community center more often for coffee or card games, yet this increased social activity fell outside the scope of this investigation. As with the self-efficacy questionnaire, participants might have found the questions fatiguing especially after already completing the self-efficacy questionnaire, as per the suggested order in the original publication (Sherer and Maddux 1982). Another study focusing more specifically on the exploration of this personal factor would likely be able to provide more conclusive results.

Stage of Change

From previously presented analysis, of the overall data and each intervention condition, we observed that stage of change significantly affected the relative improvement of physical activity. Figure 35 shows that there were more participants in the action and maintenance stage of change than in the pre-contemplation, contemplation and preparation phase. A previous, much larger study (Marcus et al. 1992), also found a large number of their participants to be either in the action or the intervention phase and suggested these phases could be subdivided to make them more descriptive. Though only 'action' in the overall regression and 'preparation' in the social awareness regression were found to be statistically significant, we observed that in both regressions the earlier stages of change (precontemplation and contemplation) had an inverse relationship with the relative improvement of physical activity while later stages (preparation and action) were found to have a direct relationship relative improvement. In the overall regression we found that action perfectly predicted

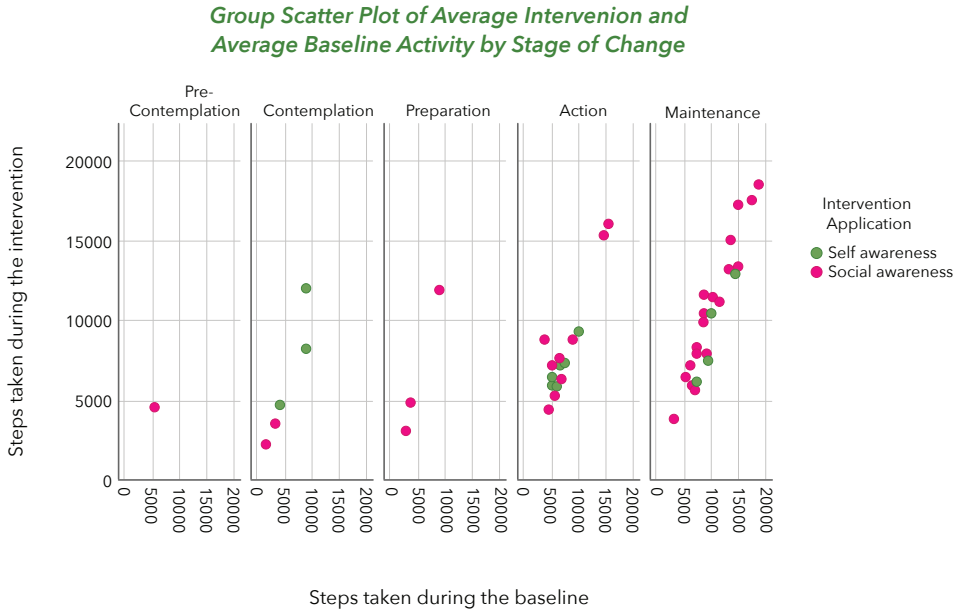


Figure 35: Spread of participant population among the different stages of change

maintenance so that these two variables had the same size effect on the relative improvement though action had a positive effect while maintenance had a negative effect.

This result can be explained as follows; people in the action stage of change, are actively trying to change their habits to increase their physical activity and thus in this process or perhaps with the help of a design intervention, they increase their physical activity. On the other hand, the maintenance phase is characterized by internalizing the change made. Those who were in the maintenance stage of change might have already reached a level of physical activity they were satisfied with before or during the baseline phase of the study, so that there was not too much more for them to improve during the intervention phase of the study. Conceivably the social awareness behavior change strategy stimulated those, who were already ready to increase their physical activity, to take that next step.

In contrast, the correlation analysis revealed a negative relationship between stage of change and the relative increase of physical activity of the people in the self-awareness condition. Implying that participants in an earlier stage of change, would be more likely to have a larger relative increase in daily steps taken. Unfortunately, the data of the self-awareness condition was not sufficient to run a regression analysis otherwise we would have been able to examine more closely the effect of each of the levels of the stages of change. For now, we can consider the possibility that people in an earlier stage of change such as precontemplation or contemplation, who were not quite as ready to change as people from the later stages of change such as action, respond well to an intervention which provides them with insight into their own habits thus making them more aware of the habits they might want to change.

These findings might suggest that people might be more receptive to behavior change strategies or to certain behavior change strategies in one certain stage of change compared to another. This effect would be an important consideration to inform the choice of which behavior change strategies would best address their target audience.

Smartphone Confidence

From the overall regression analysis, we found that the self-reported level of smartphone confidence was statistically significant to the relative improvement in steps taken, though not at every level.

From the overall regression analysis, we found that the self-reported level of smartphone confidence was statistically significant to the relative improvement in steps taken, a phone confidence level 'A little apprehensive'. The other levels of phone confidence, though not statistically significant yet still interesting to be mentioned here, were all inversely related to relative improvement in daily steps taken. The multiple regression done on the data from the social awareness condition had showed no statistical significance but again only phone confidence 'very confused' had a direct relationship while the other levels had an inverse relationship. The correlation analysis of the self-awareness condition data also resulted in an inverse relationship between self-reported phone confidence and relative improvement of daily steps taken.

Our findings from the regression analysis it seems that low self-reported confidence in smartphone use, is related to higher relative improvement in steps. Perhaps those who have low smartphone confidence, have only had very limited or no exposure to mobile applications which encourage physical activity. Then this study facilitated an introduction to such an intervention and provided the necessary technology support to enable these people to take advantage of this type of intervention for the first time. Other authors have explored how even the design of the accompanying manual could either facilitate or present barriers to the use and adoption of technology among older persons (Fan and Truong 2018). For this reason, we supplied our participants with a paper-based manual with many images specific to our study.

On the other hand, it was the extra time and support the research team might have devoted to the people who had less experience or confidence with smartphones which could have produced this result rather than the intervention application itself. Alternatively, some participants reporting low smartphone confidence might have wanted more encouragement in other endeavors as well and thus responded well to the increased attention to physical activity.

Overall, we could not differentiate which behavior change strategy better addressed participants with either higher or lower levels of smartphone confidence. However,

these results clearly indicate an opportunity for technology-based behavior change solutions, even for those who might feel apprehensive about using digital devices at first.

Comparing the Behavior Change Strategy Intervention Conditions

So far, we have found that we distributed participants without bias across the two intervention groups and that the social awareness intervention seemed to contribute to a higher increase in relative improvement. Still we were curious to see if one intervention elicited significantly better results in terms of relative improvement compared to the other.

From the overall regression analysis there is some evidence that the social awareness intervention was more motivating to participants than the self-awareness intervention, yet we were curious to investigate this point further. The Mann-Whitney U test was used here as an alternative to the independent samples T-test because the data was not normally distributed. The Mann-Whitney U test was run to determine if there were differences in relative improvement in steps between the self-awareness condition and the social awareness condition. Distributions of the relative difference in total daily steps between the baseline and intervention phases of the study for self and social awareness intervention were similar, as assessed by visual inspection, despite the difference in quantity of participants. Median relative difference in steps for participants using the self-awareness behavior change strategy (1.51) and participants using the social awareness behavior change strategy (9.10) were not statistically significantly different, $U = 213$, $z = -1.422$, $p = .155$. This additional analysis would suggest that there is no difference in effect caused by the behavior change strategies applied in these intervention applications, so that neither strategy could be construed as a better fit for this user group than the other. However, this lack of statistical result could be in part due to the incongruent number of participants in each intervention condition. The disparity in these numbers in itself point to a preference for the social awareness strategy as discussed in the next section.

Overall Limitations

The work presented here, explores certain personal factors and how these relate to the demonstration of a target behavior, in this case increased physical activity. The study was successful in that, we were able to conduct field research on factors which might inform behavior change strategies and we were able to reliably report on the analysis of the data collected, in this work. It was difficult, however, to draw much conclusive evidence from this study, as this study focused on exploring many different possibly interrelated variables. Therefore, each of the personal factors mentioned above could be addressed in more depth than we had the opportunity to do here.

It is clear that there were disproportionate test groups in this study in terms of intervention application use. In this section we look for the reasons for this disparity. By way of a Fisher's exact test, which examine the difference between independent variable groups on one dichotomous dependent variable 'dropout' ("did dropout" or "did not dropout"), we found that there was a not statistically significant difference in proportions of .144, p = .142. However, researchers of this study observed a clear preference among the participants for the social awareness intervention as compared to the self-awareness intervention. Throughout the recruitment process, there were participants who would agree to join only if they could do so with a friend from the center. Many potential participants on hearing the explanation of the study during the self-awareness onboarding workshops declined to join the study at all, so that the number of these cases are not reflected in the dropout rate. These experiences and researcher anecdotes align with literature pointing to the potential social strategies have to motivate older adults to increase their physical activity (Kononova et al. 2019).

Despite our conviction that field studies are necessary for behavior change research, our approach does present some limitations. Firstly, technology savvy participants could have looked into their step data during the baseline of the study on the research issued smartphone, if they chose to do so. Secondly, there was a disproportionate number of men and women willing to participate in the study. We have learned that there are more female members of the senior community center than male members though it is unclear if our population is perfectly representative of these proportions. In addition, the research here described was only conducted with participants of one local senior community center so that there may be some socio-cultural differences preventing this work from being generalizable to other older adult communities, as cultural characteristics can have an important impact on the design of interactive

systems (Anon 2008). For this reason, we feel it of great importance to call for new design research actions to focus on exploring these, and potentially other factors we have overlooked here, in much greater detail and among a larger breadth of users.

Conclusion

In this work we run a series of analyses to identify which personal factors relate to an increase in physical activity within each behavior change strategy condition. The insights presented in this work sometimes support and sometimes challenge accepted profiling practices widely used in design for behavior change. We discussed in detail the studied personal factors and their effect on effectiveness of the social-awareness and self-awareness behavior change strategies. We share this in order to show that in behavior change research for such a diverse population as the older adult community, personalization should rely on a combination of personal factors. We believe a better understanding about which personal factors inform the effect of the chosen behavior change strategies will help designers make more informed decisions when creating behavior change solutions. Hereby contributing to the health and wellbeing of the diverse older adult population.

Part Five

REFLECTION

In this thesis work, we have aimed to address two important research questions concerning how to effectively personalize behavior change strategies to motivate increased physical activity among older adults and how to help older adults overcome barriers to research engagement, towards the development of behavior change solutions. In this section, we will discuss our findings related to each of these research questions in order to show the importance of inclusivity in both the final design and the design process, towards interventions which stimulate healthy behavior.


BEACH 2020
Naam:
2e plaats
1e plaats
Welke drie hobbies doet u het liefst?
Wat maakt deze hobby belangrijk voor u?
Welke kaartjes passen bij uw gekozen hobby?
Complimenten krijgen over mijn kookkunsten
geeft mij een goed ontspannen gevoel
Vrolijk
Zelfvertrouwen
Ontspannen
Verrast
Trots
Welke kaartjes passen bij uw gekozen hobby?
Complimenten krijgen over mijn kookkunsten
geeft mij een goed ontspannen gevoel

CHAPTER TEN

Discussion

In this thesis work, we have aimed to address two important research questions concerning how to effectively personalize behavior change strategies to motivate increased physical activity among older adults and how to help older adults overcome barriers to research engagement, towards the development of behavior change solutions. In this section, we will discuss our findings related to each of these research questions in order to show the importance of inclusivity in both the final design and the design process, towards interventions which stimulate healthy behavior.

RESEARCH QUESTION ONE

How can we overcome the barriers to engage older adults in research related to technology development?

Reaction

We have seen that technology offers the potential to effectively personalize behavior change solutions, however we found older adults experience barriers to technology acceptance excluding them from these potential benefits. Throughout this work we have identified both barriers and facilitators to technology acceptance for our older adult participants. From our investigation described in chapter five we found that these barriers to technology acceptance also created barriers to research engagement towards the development of important health stimulating technologies. Therefore, it was essential to address these barriers to technology acceptance not just in order to allow older adults to take advantage of technology driven behavior change solutions but also to enable them to engage with research towards the development of these useful technologies.

To facilitate technology acceptance and overcome the barriers to technology acceptance older adults face in using technology driven behavior change solutions, we advocate for a codesign process. We found that a codesign process in which the older user participates in various stages of the design process not only supports the development of interventions which speak to older users' needs and values beyond their limitations but has also been shown to support technology acceptance. To facilitate this codesign process we present codesign strategies in chapter six which we implement in chapter seven. In addition, in chapter six, we identified a feeling of social connectedness as a facilitator to technology acceptance. This social connectedness can be cultivated within the codesign process or stimulated outside of organized workshops in a more peer to peer setting.

To overcome barriers to technology which limits older adult participation in important research towards the development of health promoting behavior change solutions we built on existing guidelines to create a product service system which enabled the necessary in-context research. To ensure they are usable, interventions implemented in the Research Product Service System should be codesigned with research participants. Furthermore, a research product service system addresses the various needs of a diverse older adult participant group by facilitating different levels of support the individual requires. Another important element of a successful research product service system is a system for real time data collection monitoring, which allows researchers to avoid data loss which can be caused by many unforeseen circumstances during in-context research. For more details on how to implement the research product service system please refer to chapter eight.

Discussion

We have shown how we address the barriers to technology acceptance and research engagement which our target user group faces. Throughout this work we have examined how to design for and with older adults. We have built on guidelines presented by experienced authors (Binda et al. 2018; Eisma et al. 2004; Harrington et al. 2018; Holroyd-Leduc et al. 2016; Kopeć et al. 2018; Malmborg et al. 2015). We can learn from their experiences in how to set up a research study with older adults even describing suggestions for stakeholder management (Barros, Rêgo, and Antunes 2014).

These guidelines address the limitations which many older adults face. A better understanding of these limitations can support the development of beneficial technologies; in one article authors envision an adaptive desktop/mobile operating system for older adults which addresses the limitations they discuss (Williams et al. 2013). Through their understanding of limitations related to technology acceptance, vision, multi-task processing and hearing they created a scaffold for the adoption of their proposed system; with particular attention to easy to access jargon-free tutorials and interface transferability among different devices so that the user only needs to familiarize themselves with one operating system. In addition they consider the dynamic nature of people's preferences and thus advocate the system should prompt regular reconsideration of settings and preferences so that as for example, a user's eye sight changes over time the system will easily adapt to these changes (Williams et al. 2013).

Work of this kind is important yet designing for these limitations may not yield products and services which speak to the user's desires beyond necessity, which will limit their applicability and/or enjoyability (Nurgalieva et al. 2019; Renaud and Biljon 2008). To design beyond these limitations we should consider the user's values. Design for user values has already shown merit (Berridge and Wetle 2020; Forlizzi et al. 2004; Yusif et al. 2016). In a study dignity and independence were shown to be highly important values to older adults (Forlizzi et al. 2004). Social connection strategies have shown potential to motivate older adults (Kononova et al. 2019; Visser et al. 2011) perhaps indicating that social relatedness is also an important value to older adults.

Though these values seem universal to us all, the way in which these values manifest maybe different for different generations or our focus on them might shift as we age. It does not seem likely that dignity, relatedness and independence are less important to younger adults than to older adults. However their context of living is different. Maybe the older adult faces many more limitations to their independence due to decreased mobility or health concerns, than the younger adult. Feeling that this core value is being threatened by circumstance, the older adult might put more emphasis on this universal value. Social relatedness too is universally important to people but as many older adults face loneliness this value becomes more important to address in the products and services designed for them. Thus a good understanding of the user's context is vital to design for inclusivity.

We reflect that when aiming to design inclusive interventions we need to conduct inclusive design and research processes, through codesign processes and implementing research product services systems to address multi stakeholder environments. As previously mentioned, codesign is a valuable way to include older adults in the development of technologies for older end users. To overcome these barriers to engagement, the right codesign processes and practices need to be applied. To this end, we proposed a codesign strategy built on accepted co- and participatory design methods and practices in chapter six. In chapter seven we used this strategy to create a design probe for use in in-context behavior change research. However, the strategy presented here more closely resembles a collection of best practice approaches rather than a fully conceptualized methodology. Recent work presented by Kopeć et al, 2018, describes a more formalized method to enhance participation of older adults in software development processes, called SPIRAL (Support for Participant Involvement in Rapid and Agile software development Labs) (Kopeć et al. 2018). The SPIRAL method builds on principles from participatory design and aims to empower older adults to take part in the technology development

process (Kopeć et al. 2018). This method was originally created for young start-up employees interested in appealing to the growing 'silver market' (Kopeć et al. 2018). Kopeć et al point out that the inadequacies of existing codesign methods, such as the OASIS model which only really involves end users during idea generation and how user participation in living labs is often very passive in practice (Kopeć et al. 2018). The SPIRAL method presents four important steps to empower older adults to engage in research and design processes:

1) Lower technology barrier through education (example: providing formal training complete with exams)
2) Enabling direct involvement with technology in everyday context (example: learning by doing applying the knowledge learned in the formal training)
3) Intergenerational interaction (example: hackathon where older adults and younger designers collaborate)
4) Empower older adults (example: providing introductory step-by-step experience trainings and maintaining that both younger designer and older adults have equal rights to participate in the design process)

Here we reflect on our design process and approach according to these ambitious guidelines. In the first place we did not facilitate a technology learning course at the senior community center (though this would have been a great addition), but we did teach our participants how to use our intervention application, providing both a workshop on the subject and specific hardcopy instructions. We were successful however in providing all of our participants the opportunity to both interact with the technology (in the ideation process older participants interacted with software prototypes during the walk-through exercise) and participate in intergenerational collaborations (the codesign and the in-context research were facilitated by a young research team). The SPIRAL method, calls for an "ICT literate senior with experience in direct cooperation (recommended previous steps)" (Kopeć et al. 2018), yet these kinds of prerequisites seem counter intuitive, as our aim was to include even those participants with limited experience with technology. In fact, the somewhat lengthy process of getting the older adults acquainted with technologies through an education program might deter older adults who do not already have an interest in digital technologies.

The guidelines Kopeć et al present, build on the value of older adults experience with technology and so do the authors of 'Designing Health and Fitness Apps with Older Adults: Examining the Value of Experience-Based Co-Design', whom advocate for an experience based codesign process (Harrington et al. 2018). Like us, Harrington et al were interested in how to facilitate a codesign process with older adults towards the development of health stimulating applications. In their process they asked participants to use one of three different off-the-shelf activity tracking mobile applications for a period of 10 weeks prior to participating in the codesign session, in which participants were divided up into 'user' (participants who continued to use the assigned application throughout the study) and 'none-user' (participants who stopped using the assigned application) groups (Harrington et al. 2018). From this process they were able to report on the value experience based codesign offers stating that 'user' groups contributed robust and detailed feedback built on their experiences with the provided technology. However, they also report that 'none-user' groups tended to generate more creative ideas, so they call for balancing the advantages of inviting non-users to contribute to a codesign process and leveraging the experience of 'users' (Harrington et al. 2018). In our design process described in chapter seven, we leveraged both 'users' and 'none-users'. We started our codesign process with essentially 'non-users', though they had not discontinued from any study like the 'non-users' in Harrington's work. Then we asked these participants to user test their resulting mobile application (essentially turning these 'non-users' into 'users'), which, as described in chapter seven, did indeed result in detailed feedback as Harrington et al suggest. To design inclusive technologies it is therefore important to conduct inclusive development processes. By engaging both older users and non-users we gain a better understanding of the limitations and underlying values of older adults, which provides us with valuable contextual insight, vital to the development of inclusive technologies.

Though it is clear that codesign processes are valuable toward the development of mobile technologies for older adults, more codesign processes need to be conducted to be able to draw more conclusive evidence about best practice methods. In addition, future research should focus the development of tools to support this codesign process of digital technologies to enhance both the process and the outcome. Our findings here, resonate with other work being conducted in the field. We were able to apply the useful learnings from this research question to the exploration of our other research question addressed below.

RESEARCH QUESTION TWO

How can we effectively personalize behavior change solutions for older adults to motivate increased physical activity towards a healthier lifestyle?

Reaction

To effectively personalize behavior change strategies, in an effort to motivate increased physical activity among older adults, we need to create dynamic motivational profiles. These motivational profiles should consist of a combination of personal behavioral, contextual and psychological factors, which predict the effectiveness of applied behavior change strategies. Thus, these motivational profiles are valuable indicators which could inform designer and developer decisions about which behavior change strategy to implement in behavior change solutions. So far, we have found indications that certain personal factors could be relevant in forming the motivation profile, see Table 38.

TABLE 38: PERSONAL FACTORS RELEVANT TO THE MOTIVATIONAL PROFILE

BEHAVIORAL	Level of physical activity (collected by activity tracker)
CONTEXTUAL	Age Gender Level of Technology Acceptance
PSYCHOLOGICAL	Self- and Social Efficacy Stage of Change

Beyond these relevant personal factors we explored the values important to older adults in behavior change interventions and distilled five behavior change strategy directions based on these values: *social fitness*, *improved care, self-awareness*, and *fun*, as seen in Table 15: Value themes and combined persuasive principle strategies. In chapter seven we describe a codesign process we conducted to build a research probe which implemented behavior change strategies derived from two of these

value clusters, *Social Fitness* and *Self-awareness* (see Table 30 for reflections on how we were able to implement these into the probe). In subsequent field testing described in chapter nine this probe allowed us to explore how the identified personal factors related to the behavior change strategies derived from values important to older users. From these investigations we found an indication that social awareness strategies might be more likely to be effective with older users who are already in the preparation stage of change while self-awareness strategies might be more appropriate for older users who struggle with technology acceptance, are at an earlier stage of change and of more advanced age, as summarized in Table 39.

TABLE 39: SUMMARY OF USER PROFILES LINKED TO EFFECTIVE BEHAVIOR CHANGE STRATEGIES

USER PROFILES	*EFFECTIVE BEHAVIOR CHANGE STRATEGIES*	*PERSUASIVE CATEGORIES**	*SUGGESTIONS FOR OPERATIONALIZATION**
PROFILE A: *PREPARATION STAGE*	SOCIAL AWARENESS	Primary task support	Self-monitoring
			Personalization
		Social support	Social facilitation
PROFILE B: *LOW SMARTPHONE CONFIDENCE, AT AN EARLIER STAGE OF CHANGE AND OF ADVANCED AGE*	SELF-AWARENESS	Primary task support	Self-monitoring
			Personalization
		System Credibility Support	Expertise
			Real-world feel

* Persuasive categories and principles from Oinas-kukkonen and Harjumaa 2009

However, behavior change is very complicated and the older adults research group very diverse so that there are limitations to these findings. Therefore, we call for future research to investigate a broader sample of personal factors and an increased number of behavior change strategies in order to build our knowledge of the relationship between personal motivational profiles and applicable behavior change strategies. Doing so will make future behavior change interventions more effective and thus help people attain their target behaviors towards healthier, happier lives.

Discussion

In our reaction to the above research question concerning how to effectively personalize behavior change strategies for older adults, we address both important factors of personalization and opportunities for operationalizing these. Here we will first discuss our reflections on opportunities for personalizing behavior change interventions and then reflect on factors of personalization.

Operationalizing behavior change interventions

In this thesis we will focus on questions related to which personal factors can be used to personalize behavior change interventions and how to engage older adults in the development of these technologies. However we do not address in depth the kind of personalization these behavior change solutions should use, in terms of user-driven personalization, system driven personalization or perhaps adaptive interfaces.

We are perhaps most familiar with user-driven personalization in which the user has the opportunity to select settings to manage the system's interaction according to their wants (Fan and Poole 2006; Lee 2013). System-driven personalization takes a proactive approach by automatically personalizing content either based on user input (often in the form of surveys) or based on users past behaviors (Lee 2013). Adaptive interfaces are the most dynamic as their elements of interaction (available options, information display, functions etc.) are adjusted based on contextual information measured by the system. Such as a music streaming mobile application which changes its interface to a more drive-safe visualization with limited options when the mobile device detects that it is in motion.

There are benefits and limitation to each of these systems or personalization strategies. For example though user-driven personalization provides the user the most control of their system interaction, users may not always have a clear understanding about what their needs and preferences are in a way which can effectively define these system integrations (Lee 2013; Riquelme 2001; Simonson 2005). Though system driven personalization approaches allow the user to enjoy personalized interaction which they might not have been able to create themselves without the effort of managing this personalization themselves these systems work best when the user's context and preferences remain constant and often fall short of meeting the dynamic needs of users over time (Lee 2013). In addition, when users do not have insight nor control over these automatic personalization systems, such as those used by

search engines or some social media providers, there is a risk that users miss out on exploring information beyond the knowledge and perspectives they already have (Grömping 2014; Pariser 2011). Though adaptive interfaces have the potential to be better contextualized to the user's dynamic needs, an interface that changes might be confusing to users (Gajos et al. 2006).

A better understanding of how these kinds of personalization could support the implementation and the operationalization of the results presented here, yet this investigation was outside the scope of this thesis and better reserved for future work.

Another aspect of operationalizing suggested behavior change interventions requires us to consider how the necessary personal data pertaining to behavioral, psychological and contextual information is collected. In this work we have made a start at identifying which personal traits are relevant to informing behavior change strategies in order to minimize the data collection load on users. This is important because collecting and storing irrelevant personal user data results in avoidable privacy and security concerns and, depending on how this information is collected, might cost the user time and effort unnecessarily. The data collection methods used in the previously described investigation depend on a combination of technologically tracked data, hardcopy surveys, and diary like cultural probes which are not feasible for use on a large scale. Though unobtrusive sensors offer opportunities to decrease the time and effort required on the part of the user, these technologies might be even more difficult to understand for older adults with limited technology acceptance presenting serious issues concerning informed consent. That is why, to ensure users are comfortable with the data being collected and that the data collection process itself does not overtax users we need to continue to engage older users in the development of these beneficial behavior change technologies. Inclusivity in the design process by empowering older end-users to participate in the design process of monitoring and behavior change technologies enables the design of more inclusive products and services.

Reflection On What To Personalize

Here we have made a start in linking motivational profiles to behavior change strategies in order to personalize behavior change interventions effectively. However, this is only the start as we were only able to test with relatively small groups of older adult individuals and for a relatively short period of time. More research needs to be done to draw conclusive evidence about exactly which personal factors are relevant to the motivational profile and how these profiles relate to the many behavior change strategies. We suggest working with a larger variety of senior community centers across many locations and implementing interventions for at least 6 months to a year in order to better measure behavior change instead of only action, as we might have done here. We also call for more behavior change strategies to be tested, because though our A/B test described in chapter nine yielded some interesting results there are many more behavior change strategies which need to be tested beyond only self and social awareness of physical activity. For future work it might also be interesting to investigate if relationships between motivational profile and behavior change strategy remain the same across different target behaviors. For example, if, as we found in chapter nine, the self-awareness behavior change strategy effectively addresses people with low smartphone confidence, at an earlier stage of change and of advanced age to increase their physical activity will this same strategy also be effective for this same profile of user to increase nutrition in their diet? Furthermore, the investigation of these profiles is challenging because we would have to conduct a multifactor analysis to make sure that each factor in the motivational profile is relevant to behavior change.

The PreventIT Horizon2020 consortium has recently contributed valuable work in the domain of mobile health technology development with and for older adults and plan to conduct a randomized controlled trial for more than six months with a mobile application which applies no less than 30 behavior change tactics (Boulton et al. 2019), answering many of our wishes for future research. They aim to develop a theory-based behavior change solution to stimulate healthy habit forming in people between the ages of 60 and 70, through a codesign process of the eLiFE app (Boulton et al. 2019). Like us they use a codesign process to design their application, see the value of real-time-monitoring and recognize the importance of personalizing behavior change interventions. Due to the many similarities in our research ambitions we will discuss the similarities and differences in our findings and process here.

Though both our work, presented here, and the PreventIT project aim to contribute to the body of knowledge on how to facilitate behavior change in older users toward healthier lifestyles, there were some specific differences in approach. The eLiFE application is a much more high-fidelity prototype and includes many more features than the REACH HealthyTogether, which was only created as a design research probe. Our target audiences also varied: where the PreventIT consortium were working with people between the ages of 60 and 70 (Boulton et al. 2019), our target audience was a little older: the mean age in our final evaluation study was more than 72 years. Where the PreventIT application uses the instructor as social support (Boulton et al. 2019), we aimed to connect older adults to their peers from the same senior activity center. Most importantly, though we agree that personalization is important to behavior change, the approaches we each took to personalization differs.

The approach the PreventIT team took to personalization and the one we suggest here differ. PreventIT personalizes messages supplied by the eLiFE app in terms of activity preferences, user input and some vitality indicators, while we suggest personalizing behavior change interventions based on motivational profiles consisting of a combination of psychological, contextual and behavioral factors. The eLiFE system push-messages are personalized based on an impressive variety of factors including; vitality indicators (during the intake of the program balance, physical activity, and strength are assessed by an activity instructor), measured activity (users are alerted when they have been sedentary for too long) and user input such as activity preferences, personal goals, planned activities (application allows users to plan their activities into their daily routine) and user responses to prompts (users can, for example, say they didn't do their activity because they didn't feel well or because they forgot) (Boulton et al. 2019). The Health Action Process Approach (HAPA) (Schwarzer 2008), which aims to bridge the intention action gap, underpins the eLiFE as its theoretical basis (Boulton et al. 2019). The PreventIT consortium mapped these push-messages to constructs in the HAPA (Schwarzer 2008) and to behavior change techniques as defined by Michie et al (Michie et al. 2013). Yet they do not construct clear user profiles which could inform which behavior change tactics to apply or which messages to send. Profiling users based on, among others, psychological factors could inform which behavior change tactics could best support the user's journey to increased physical activity. For example, knowing that a user has a high *action self-efficacy* (Schwarzer 2008), but a low *recovery self-efficacy* (Schwarzer 2008), could indicate an increased need to emphasize creating attainable personal goals and messages to that user could relate more to anticipating and overcoming setbacks. Knowing that a user has a low action self-efficacy, but a relatively high recovery self-efficacy, the intervention could

focus more on providing encouraging messages and lowering the threshold to start working towards new healthy habits. In this way, we suggest adding a new dimension to personalization of behavior change interventions beyond preferences and physical limitations. For users with low technology acceptance it is essential not to overwhelm them with messages and information, therefore it is important to predict exactly which behavior change techniques or strategies are appropriate for a specific user at a specific point in time and during their dynamic behavior change process. Boulton et al understand the importance of theory-based behavior change interventions and of personalizing these behavior change solutions, yet it does not seem that they use the factors indicated by their preferred behavior change approach to inform which behavior change techniques should be applied in the messages they send to their users.

We see an opportunity to use their application, mapped push-messages and intervention infrastructure to further investigate the link between motivational profiles and behavior change strategies. To go beyond the few relationships we have identified in this thesis, we suggest conducting a randomized controlled trial, similar to the evaluation study conducted in chapter nine, in which the effect of push-messages mapped to behavior change techniques on level of physical activity over time are examined according to the user's psychological, behavioral and contextual personal factors. From this data we could generate motivational profiles based on which combination of personal factors indicates increased sensitivity towards a certain behavior change strategy. Making the important link between motivational profile and to behavior change tactics or strategies in the messages which seem to be most effective. The resulting motivation profiles should then be subjected to testing. As there are many factors at play here, including context and timing, ongoing living lab research is needed to discover the behavior change strategies which best address certain motivational profiles throughout the dynamic behavior change process, to create more effective behavior change solutions towards healthier happier lives.

Overall Limitations

Behavior change is a dynamic process and it takes time for people to adopt new behaviors so one limitation to our overall process as described in this work, is the lack of longitudinal studies to ascertain actual behavior change. A literature review of articles which describe studies measuring physical activity and testing physical activity stimulating interventions by community dwelling older adults between 1990 and 2018 calls for more long-term studies, with theory-based interventions (Jonkman et al. 2018). Yet most of the studies cited here only collected 7 days of data with only one study exceeding 14 days, reportedly collecting 30 days' worth of physical activity data during their intervention (Jonkman et al. 2018), which is comparable to the duration of our evaluation study. However, we agree that in order to gain more information about how behavior changes over time, there is a need to conduct longer term evaluations with measured physical activity data and activity promoting health interventions.

Due to the limited duration of our evaluation study it is unclear whether we could claim technology adoption or whether the use of our interventions merely represent technology acceptance. Though the use of our interventions does indicate an initial acceptance of the mobile application designed through our codesign process, longer term in-context research would have to be conducted to see if users genuinely adopted our proposed technologies. Determining whether our design probe elicited technology adoption beyond initial acceptance was outside the scope of this research. In future work we hope to see the contributions made here applied in product prototypes and those subjected to longitudinal in-context testing.

When working with more difficult to reach target users we have to be especially aware of recruitment biases. In our study we certainly will have experienced some recruitment biases because we mainly recruited from one local senior community center, the Ontmoet en Groet center in Eindhoven, The Netherlands. This could lead to certain socioeconomic and possibly cultural biases. Our research aimed to ultimately activate sedentary older adults, but the population of older adults whom are members of the community center generally don't belong to the least active older adults; those who barely leave their homes. Many of these older adults are at risk of loneliness, which is a dangerous condition as it can depress one's inclination to go out to get exercise and socialize. Though a pertinent subject among the topics of older adult wellbeing, assessing loneliness was outside the scope of this work,

but is mentioned here to illustrate that there are many subgroups of older adults, who could benefit from design interventions to stimulate physical activity yet whom we were not able to recruit to our study. Other subgroups which could have been under-represented in our study are people who have an international background and have trouble speaking Dutch, the prevailing local language, or those who have a strong aversion to technology possibly due to exceedingly low levels of self-efficacy on that front. As is the case in many research efforts with harder to reach populations, we probably only succeeded in recruiting older adults who are relatively confident in trying new things or feel comfortable enough in social settings to participate in our study's workshops. We did our best to communicate positive assuring details about the workshops and study during recruitment and even asked the volunteers and employees of the community center to help us recruit people who might not put themselves forward, nevertheless it is important to be aware of these recruitment biases.

Ethical Consideration

When conducting research with human subjects, it is our responsibility as researchers to think critically about the ethics of what we are doing and how.

Once an older lady expressed concern lest we be making robotic nurses to replace the kind nurse that helped her with her compression stockings each morning. This was not the aim of our work, but it illustrates a good point; as designers and future thinkers we envision a future, often for others, which they have to live in. Let's say that we were aiming to build a robotic home nurse, would it have been right to persuade this person who did not agree with that outcome to contribute towards it by participating in our research? Or would it have been valuable to persuade someone who was so against this concept to weigh in on it in order to improve it?

In the research described in this thesis we did our best to conform to available University, EU and community center guidelines on privacy and ethics (European Commission 2018b, 2018a). Yet, conducting ethically upright research is more than correctly following guidelines, as especially those related to privacy and cyber security are often outdated. In each of our studies we asked participants to sign an informed consent document. We asked a room full of people who were about to unlock their first touch screen if they agreed that we would keep their names and ages in an Excel file, saved locally on an encrypted drive. They all signed the informed consent, but did they really know what they were consenting to; could they really oversee the risk involved with this research? Conducting research in the name of a university or for European Union consortium comes with responsibility which should not be taken lightly, because often it seems research participants sign the informed consent not based on the detailed study protocol researchers outline but based on their trust in the institution the research team represent to them, such as the local university. Despite our suspicions that some participants were not able to genuinely grasp all aspects of our protocol, this does not give researchers permission to exclude these individuals from research which could ultimately benefit their lives, or the lives of people like them. Otherwise medical doctors would no longer be allowed to treat lay people. When designing with these target users, researchers have an extra responsibility to be vigilant to uphold our own personal moral code of ethics, sometimes beyond the guidelines of the institution they represent and think critically about the risks, limitations and implication of our work.

So, who are we to tell people they need to change? In the domain of persuasive technology, one could say that there are three types of people: 1) actors, 2) intenders and 3) non-intenders. Those who act are already engaging in the target behavior; they are our examples. Intenders are those who would like to be actors but face obstacles which present design opportunities for us. In general, we can assume many, if not, most of the participants we worked with throughout this research belong to this category. Intenders are ready for change and generally respond well to appropriate design interventions. The non-intenders are the precontemplationists, who don't mind that they lead sedentary lifestyles or don't eat the recommended servings of fruit a day. Though the interventions proposed here are not appropriate for this difficult to reach target group, with a better understanding of the obstacles they face, a better insight into how to create motivational profiles and how to address each of these profiles with behavior change strategies, in future we might even be able to support this group to move from non-intenders to intenders.

CHAPTER ELEVEN

Conclusion

To address our first research question, we propose a way of creating motivational profiles linked to behavior change strategies. To address our second research question, we provide design criteria for the setup and execution of design research to overcome the barriers to research participation. Here we establish the importance of inclusivity in both the final design solution and in the design process, so that even initially non-technology savvy older adults can benefit from technologies potential to motivate healthy behavior change. In this thesis, we describe a new way to approach behavior change personalization for a specific target audience with the ambition of contributing to the substantial body of knowledge on behavior change. The purpose of sharing our experiences is also to enter the conversation on how to design meaningful products and services which motivate increased physical activities towards healthy aging.

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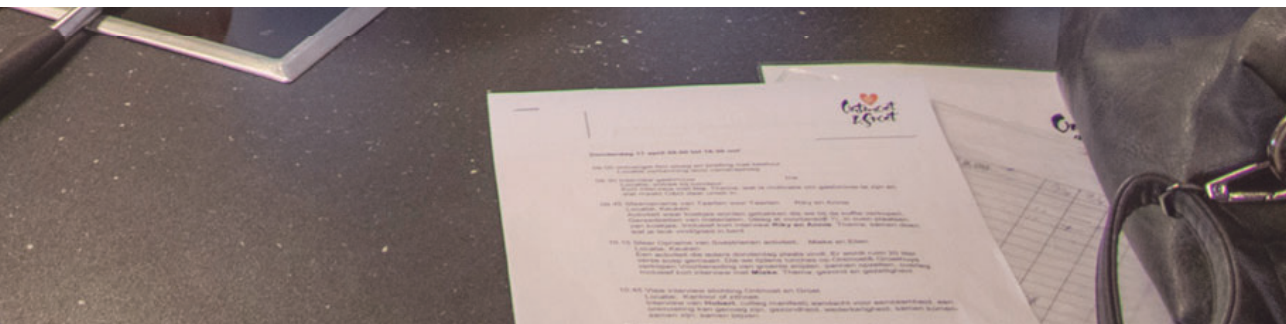
APPENDIXES


BALLIN
AMSTERDAM



Samenvatting

Wanneer we ouder worden, hebben we de neiging om minder actief te worden, wat de ernst van verschillende chronische aandoeningen verergert, waardoor onze behoefte aan zorg toeneemt. Fysieke activiteit heeft aantoonbare voordelen voor ouderen, waaronder het ondersteunen van de zelfstandigheid, verminderen van fragiliteit en het verbeteren van het algemene welzijn. Om mensen te motiveren meer fysiek actief te zijn, is een persoonlijke aanpak belangrijk, want er is niet één oplossing die voor iedereen even goed werkt. Er is dus een duidelijke behoefte om een gedragsveranderende oplossing te ontwerpen om ouderen te motiveren om een gezonde hoeveelheid fysieke beweging te hebben. Niet alleen om de druk op het Europese gezondheidssysteem te verlichten, maar veel belangrijker nog om het geluk en welzijn van de ouderen zelf te vergroten.

Technologie kan een belangrijke rol spelen, omdat dit mogelijkheden biedt om doormiddel van metingen, (bijvoorbeeld van stappentellers of activiteitstrackers) ouderen meer inzicht te geven in hun eigen fysieke activiteit. Alhoewel gedragsverandering al veel bestudeerd is, is er nog onvoldoende onderzoek gedaan naar gedragsveranderingstechnologieën voor ouderen. Het is daarom onduidelijk hoe je ouderen kunt profileren, zodat je de juiste gedragsveranderingsstrategie kunt bieden om een individu te motiveren voldoende fysiek actief te zijn. Dit gebrek aan kennis komt gedeeltelijk door de barrières die er zijn om een belangrijke subgroep van de bevolkingsgroep ouderen te betrekken bij onderzoek naar de ontwikkeling van nieuwe technologieën. Juist in deze diverse bevolkingsgroep loopt de ervaring met technologie enorm uiteen.

Daarom hebben we de volgende twee onderzoeksvragen centraal gesteld:

OV1: Hoe kunnen we effectief gedragsveranderingsstrategieën personaliseren voor ouderen om ze te motiveren meer fysiek actief te zijn en hierbij bijdragen aan een gezonde levensstijl?

OV2: Hoe kunnen we de barrières wegnemen om ouderen te betrekken bij onderzoek gerelateerd aan technologieontwikkeling?

Methodologie. We voerden een algemeen onderzoeksproces uit dat bestond uit een verkennings-, ontwerp- en evaluatiefase om onze onderzoeksvragen te beantwoorden. Tijdens de verkenningsfase hebben we twee onderzoeken uitgevoerd. Het eerste onderzoek was bedoeld om beter te begrijpen welke gedragsveranderingsstrategieën mogelijk veelbelovend zijn voor ouderen. De tweede studie was een veldstudie om een beter begrip te krijgen van de barrières waarmee ouderen worden geconfronteerd wanneer ze deelnemen aan onderzoek met technologische prototypes. In de ontwerpfase hebben we een systeem gebouwd om ouderen bij onderzoek te betrekken en hebben we twee mobiele applicaties ontwikkeld om meer lichaamsbeweging te stimuleren. In onze laatste studie hebben we het effect geëvalueerd van de twee mobiele applicaties op de fysieke activiteit van de deelnemer en of het systeem dat we hebben gemaakt, onderzoeksbetrokkenheid ondersteunt in een in-context onderzoek naar de ontwikkeling van technologie voor gedragsverandering.

Resultaten. In de eerste studie van onze verkenningsfase analyseerden we de resultaten van twaalf iteratieve gebruikersgerichte ontwerpprocessen gemaakt door studententeams en ontdekten dat 'zelfbewustzijn' en 'sociale fitheid' de twee meest gebruikte strategieën waren om meer fysieke activiteit bij ouderen te stimuleren (Valk et al.2017). In de tweede studie hebben we belemmeringen en faciliterende factoren geïdentificeerd die helpen bij de acceptatie van technologie. Dit hebben we gedaan door een kritische reflectie op de gegevens, die zijn verzameld van 44 thuiswonende ouderen die gedurende 3 maanden een activiteitstracker hebben gedragen. (CAL Valk et al. 2018). Op basis van deze resultaten hebben we een reeks codesign-strategieën voorgesteld om de acceptatie van technologie onder ouderen te verbeteren en te gebruiken bij het ontwerp van toekomstige aciviteitstrackers (C. Valk et al. 2018). Deze strategieën werden in onze ontwerpfase gebruikt om een specifiek product-service-systeem te creëren om oudere volwassenen te ondersteunen bij een in-context gedragsveranderingsonderzoek (C.Valk et al. 2019). In de ontwerpfase hebben we ook twee mobiele applicaties gemaakt, via een codesign-proces met ouderen, die de gedragsveranderingsstrategieën implementeerden die we in de eerste studie hebben geïdentificeerd. Tijdens onze evaluatiefase hebben we het product-service-systeem gebruikt, dat we hebben gemaakt om de

negen weken durende gerandomiseerde gecontroleerde studie (N = 53) in-context evaluatie van de twee mobiele applicaties mogelijk te maken (C. A. L. Valk et al. 2019). Op basis van de statistische analyse van de gemeten stappen en de verzamelde vragenlijsten hebben we voorgesteld hoe we effectieve motivatieprofielen kunnen maken om deze gedragsveranderingsstrategieën te personaliseren om zo meer fysieke activiteit voor oudere gebruikers te stimuleren.

Bijdrage. Om onze eerste onderzoeksvraag te beantwoorden, hiervoor stellen we een manier voor om motivatieprofielen te creëren die gekoppeld zijn aan strategieën voor gedragsverandering. Om onze tweede onderzoeksvraag te beantwoorden, hebben we ontwerpcriteria opgezet voor de uitvoering en opzet van design onderzoek om de barrières voor onderzoeksparticipatie weg te nemen. Hier stellen we het belang van inclusiviteit vast, in zowel de uiteindelijke ontwerpoplossing als in het ontwerpproces, zodat zelfs aanvankelijk niet-technologisch onderlegde ouderen kunnen profiteren van de potentie van technologie om een gezonde gedragsverandering te motiveren.

CURRICULUM VITAE

Carlijn Valk was born on April 18th, 1991 in Leiden, but moved abroad by the age of three, first to Oxfordshire, England, and then to Houston, Texas USA. After graduating from her BFA in Industrial Design from Carnegie Mellon University in Pittsburgh, Pennsylvania, in 2014 and working for a medical design consultancy in Baltimore, Maryland, she came to the Netherlands to pursue her graduate degrees. In 2016 she graduated cum laude from the Master of Science degree in Industrial Design from Eindhoven University of Technology.

Here in the Systemic Change research group, her PhD focused on how designers could more effectively personalize behavior change strategies to motivate increased physical activity towards healthier lifestyles. Her research on this topic was conducted in close collaboration with several international partners both from industry and research institutes, funded by the European Union's Horizon 2020 research and innovation project, REACH. Over the course of her PhD she was invited to present her research findings at several different conferences in seven different countries across three continents. Throughout her research Valk has favored a mixed method approach and research within a living lab to better understand the dynamic process of behavior change. She is passionate about enabling her users to participate throughout the design process and enjoys coming up with creative ways to engage end users.

Next to her research, as a member of the REACH core team, she helped facilitate consortium workshops and collaborated with consortium partners in Munich, Geneva, Brussels and Eindhoven. The important contributions achieved by the REACH consortium were presented in an internationally visited Exhibition in Denmark, May 2019, for which Valk collaborated closely with a small team from DTU and TUM to conceptualize and realize the exhibition design. Also during her PhD she discovered her enthusiasm for teaching young designers and gained international teaching experience when she taught at a summer school at Zhejiang University.

Research Output

2020

Kulev, I., **Valk, C.**, Lu, Y. et al. Recommender System for Responsive Engagement of Senior Adults in Daily Activities. Population Ageing (2020). https://doi.org/10.1007/s12062-020-09263-w

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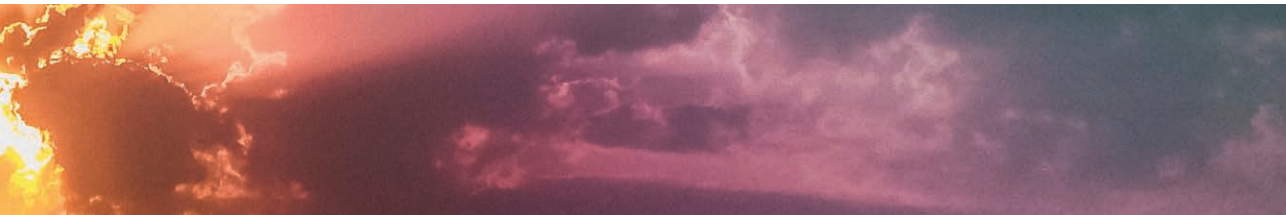
WORDS OF GRATITUDE



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Thank you

I wrote an entire dissertation of more than 200 pages, but these next few were the hardest to put into writing. Sincere gratitude is a feeling beyond words. Yet it should be expressed, because the work presented to you here would not have been possible without the kind help and support of so many really important people, who I am grateful to know. So please accept the following attempts to put this feeling into words as a genuine expression of thanks.

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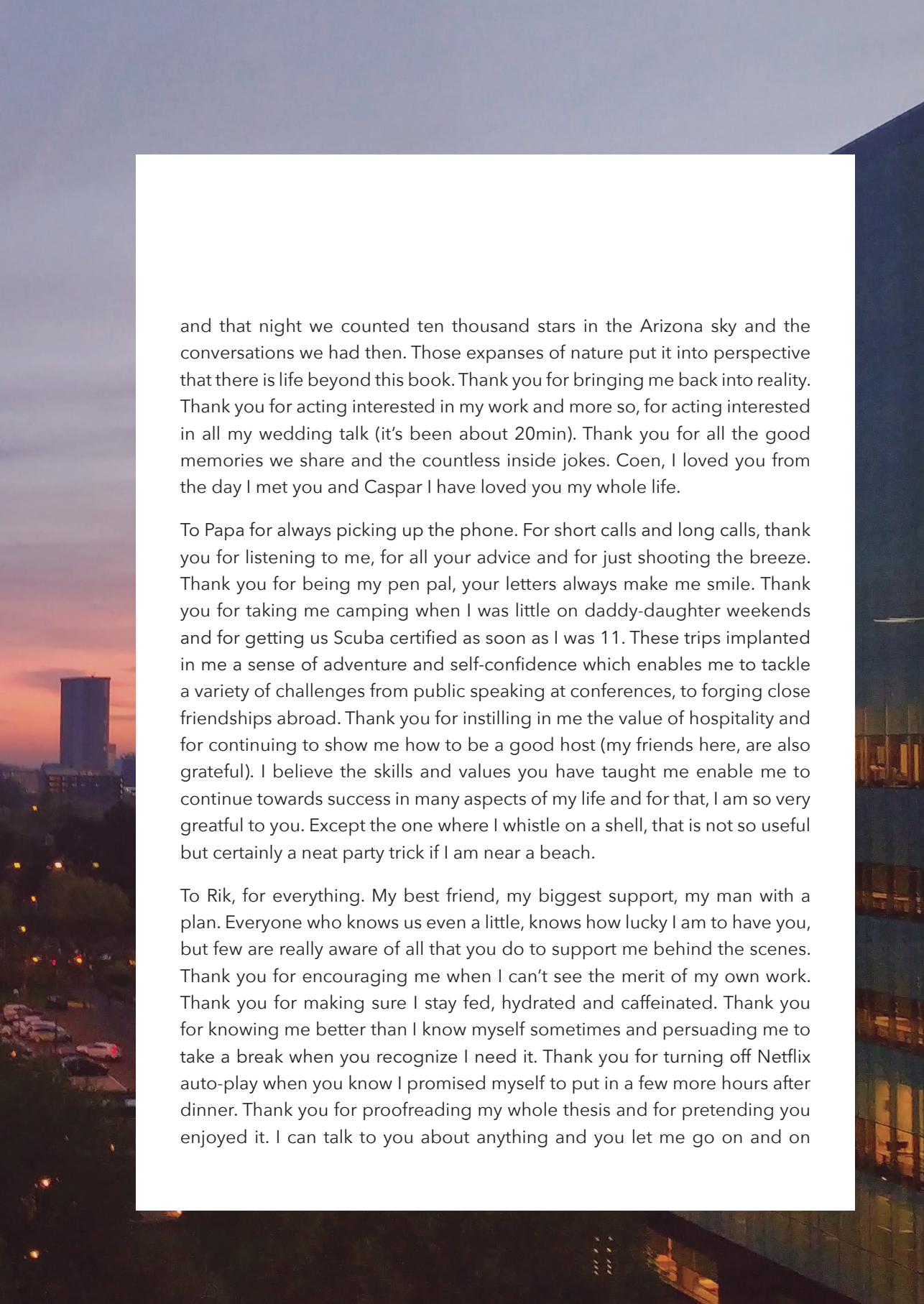

and that night we counted ten thousand stars in the Arizona sky and the conversations we had then. Those expanses of nature put it into perspective that there is life beyond this book. Thank you for bringing me back into reality. Thank you for acting interested in my work and more so, for acting interested in all my wedding talk (it's been about 20min). Thank you for all the good memories we share and the countless inside jokes. Coen, I loved you from the day I met you and Caspar I have loved you my whole life.

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To Mama for being the reason I believed in myself enough to go on this amazing adventure,

To those no longer with us,

To everyone for supporting me,

Thank you.


Today we are living
‘*the good old days*’
we’ll reminisce about
when we are older

ABOUT THIS BOOK

In this doctoral thesis, Valk explores the importance of engaging older end users in in-context research toward the development of behavior change solutions. This work aims to explore how to effectively personalize behavior change solutions to motivate behavior change toward increased physical activity among older adults, by investigating the link between applied behavior change strategies and behavioral, contextual and psychological personal factors. In five parts, background, explore, design, evaluate and reflect, Valk describes several studies throughout her design and research process to address her two overarching research questions.

The approach taken here converges knowledge from the domains of living laboratories, codesign, and existing experience of design research with older adults. Based on the experience with the designed Product Service System, guidelines are provided to support other researchers setting-up a living laboratory study with older adults to explore technology's potential to motivate behavior change. This work culminates to the presentation of certain motivational profiles consisting of behavioral, contextual and psychological personal factors, which indicate the effectivity of certain behavior change strategies. This work aims to contribute to knowledge in the behavior change science, to support the creation of behavior change solutions to motivate older adults to engage in a healthy amount of physical activity, not just to alleviate the pressure on Europe's healthcare system but more importantly to support their happiness and wellbeing.